CONTINUOUS IMPROVEMENT MODEL FOR SMALL SCALE MANUFACTURERS IN KENYA

ZACHARY MWITHIGA KITHINJI

MASTER OF SCIENCE

(Mechanical Engineering)

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

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Continuous Improvement Model for Small Scale Manufacturers in Kenya

Zachary Mwithiga Kithinji

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature:.. Date................................

Zachary Mwithiga Kithinji

This thesis has been submitted for examination with our approval as the University Supervisors.

Signature:.. Date................................

Prof. S.M. Maranga

JKUAT, Kenya

Signature:.. Date................................

Dr. S.O. Nyamwange

UON, Kenya

DEDICATION

Dedicated to Mercy and Jeff Ethan for the support and love.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CI	Continuous Improvement
COYA	Company of the Year Award
DPMO	Defects per Million Opportunities
DMAIC	Design Measure Analyze Improve Control.
DoE	Design of Experiments
ES	Expert System
FKE	Federation of Kenya Employers
FMEA	Failure Mode and Effect Analysis
ISO	International Organization for Standardization
IT	Information Technology
JIT	Just in Time
KAM	Kenya Association of Manufacturers
KEBS	Kenya Bureau of Standards
KIRDI	Kenya Industrial Research and Development Institute
KQA	Kenya Quality Award
M	Mean
MR	Mean Rank
MSED	Micro and Small Enterprise Development
QFD	Quality Function Deployment
QM	Quality Management
QS	Quality Systems
PDCA	Plan Do Check Act
SD	Standard deviation

SPC	Statistical Process Control
TQM	Total Quality Management

ABSTRACT

Continuous Improvement (CI) is a quality management philosophy that approaches the challenge of product and process improvement as a never ending process of achieving small wins. Quality management (QM) cannot be assured unless some objective assessments are undertaken. A number of tools and techniques are available to conduct such analysis. Some of these tools include flow charts, Pareto analysis, histograms, scatter diagrams, pie chart, cause and effect diagrams, and brainstorming among others. Several CI models and methodologies have been developed that integrate the use of these tools in the operations of the firm. A preliminary survey indicated that the status of the use of these models in Kenya was unknown. A literature review indicated the difficulties encountered in using these quality improvement tools as not knowing what quality tool to use, using a quality tool incorrectly, using a quality tool for the wrong application, and not knowing when to use a quality tool.

The objectives of this research were to carry out a survey on the status of use of the CI models in Kenya, and to develop and validate a computer based CI model applicable to small scale manufacturers. The model aids in tool selection in the quality improvement projects. A survey was carried out by questionnaires, site visits and interviews to help determine the status of CI in Kenya. 174 questionnaires were sent to various manufacturing organizations from which 58 companies responded and they were all found usable.

The survey findings revealed that there is a general awareness of the quality in the Kenyan manufacturing sector but there is a statistical correlation on the level of implementation and size of the company, age of the company and target market for the firm's products. An algorithm that integrated CI methodologies and tools was developed and validated by testing it in two small scale manufacturers. The computer code allowed the user to

identify the correct tool at the proper time in the problem-solving process. This assisted the problem solver to efficiently and effectively work toward problem solution.

The research contributed to a general understanding of the extent of the use of CI with respect to quality management among the Kenyan manufacturers, and the developed computer code will find use in among the Kenyan manufacturers who are keen on improving the quality of their products by reducing the number of defects or predicting defects from their operational data.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Continuous Improvement (CI) is a management practice that approaches the challenge of product and process improvement as a never ending process of achieving small wins. The technique seeks continual improvement of machinery, materials, labor utilization, product and production methods [1].

The tools and techniques used for CI at the production level are flow charts, pareto analysis, histograms, scatter diagrams, pie chart,cause and effect diagrams, brainstorming, stratification, Taguchi methodology, capability indices, benchmarking, check sheets, control charts and to a much lesser extent, design of experiments. Various methodologies or models have been developed to integrate the use of the tools in the operations of the firm. Different models focus on the use of particular tools and in a particular sequence. Some of these models include Demming Wheel, lean manufacturing, six sigma, balanced scorecard, kaizen, and hybrid models.

The use of the above tools improves process efficiency, product quality and process capability while reducing process variability, costs of poor quality such as scrap, rework and other failure costs [2]. Many companies in Europe, Asia and USA have used these tools with success as part of their Continuous Improvement (CI) models [2, 3]. However there is very little documentation of the use of these models in the Kenyan manufacturing sector.

A Preliminary survey was carried out by interviewing quality professionals working with Kenya Association of Manufacturers (KAM), Federation of Kenya Employers (FKE), Kenya Bureau of Standards (KEBS), and Kenya Industrial Research Development Institute (KIRDI). The survey indicated that some Kenyan large scale manufacturers with multi-national links use some of these CI models. There is little evidence of use of the tools among the small scale manufacturers in Kenya. The true status of the usage of these tools was unknown.

A manufacturing organization is classified as small, medium or large scale depending on the number of employees, ownership (public or private) or the turnover [4]. In this research, the classification is based on the number of employees: less than 50 is a small scale manufacturer; between 50 and 100 is a medium scale manufacturer; and more than 100 employees, a large scale manufacturer. This classification has been used in Kenya manufacturing sector surveys conducted by Kenya Association of Manufacturers [4].

1.2 Problem Statement

The status of Continuous Improvement with respect to Quality Management among the manufacturers in Kenya is not known. The extent of application of the Quality Management tools among the manufacturers is also unknown. In order to develop tools and methodologies suitable for the local manufacturers, it is important to determine the status of Continuous Improvement in the local industry.

Research carried out on use of quality management tools indicated the difficulties encountered in using these quality improvement tools were not knowing what quality tool to use, using a quality tool incorrectly, using a quality tool for the wrong application, and not knowing when to use a quality tool. This is more severe for small scale manufacturers in developing countries who find it hard to hire and retain qualified quality management personnel [3]. To address these problems, computer based model was proposed. Such a model would be easy to use, and cheaper to acquire and maintain and would guide the unskilled in tool selection and usage.

1.3 Objectives

The objectives of the research were:

- to determine the status of Continuous Improvement in Kenya; and,
- develop and validate a computer based Quality Management program that is applicable to small and medium scale manufacturers in Kenya.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definitions

2.1.1 Quality

The definitions of quality in the literature are;

- Quality is fitness for use [5],
- Quality means conformance to requirements [6],
- Quality should be aimed at the needs of the customer, present and future [7],
- The lack of quality is the loss a product imparts to the society from the time the product is shipped [8].

All the above definitions focus on the customers and their needs.

Garvin [9] classifies five approaches to defining quality; transcendent, product-based, user-based, manufacturing-based and value-based quality. According to transcendent approach, quality can not be defined precisely, but can be recognized through experience. Product-based definitions view quality as a precise and measurable variable where higher quality can only be obtained at a higher cost. User based definitions are founded on the premise that the product that best satisfies the consumer preferences has the highest quality. Manufacturing based definitions purport that any deviation from a design or specification implies a reduction in quality. Value-based definitions define quality in terms of prices versus features or performance.

Garvin concludes that it may be beneficial to adapt multiple approaches to quality. Initially, it may be favorable to have a user-based approach and identify the market requirements. At the design stage, a product-based quality may be desired in order to transform the design characteristics to specifications. A manufacturing-based approach during manufacturing can help ensure that the manufactured products meet the specifications. The focus of this research is the manufacturing function of the organization, and hence manufacturing-based definition of quality is used [9].

2.1.2 Continuous Improvement

According to the ISO 9000 standard, Continuous improvement is the everyday activities executed by a company in order to enhance its ability to meet customers' demands. Continual improvement can be achieved by carrying out internal audits, performing management reviews, analyzing data, and implementing corrective and preventive actions. Specifically, it is the ability to continuously minimize waste, reduce response time, simplify the design (of both products/service and processes), and improve quality in order to meet customer's needs and wants more proficiently [10] .

Continuous Quality Improvement (CQI) can be defined as a "management approach to improving and maintaining quality that emphasizes internally driven and relatively constant (as contrasted with intermittent) assessments of potential causes of quality defects, followed by action aimed either at avoiding a decrease in quality or else correcting it at an early stage." [11] Today it is widely accepted that quality initiatives should no longer be a one time solution procedure to solve a particular problem but rather an inherent value assurance methodology in the production system.

2.1.3 Quality Management

The ISO 9000 standard defines Quality Management (QM) as the entire activities that management execute in an effort to implement their quality policy [10]. These activities include quality planning, quality control, quality assurance, and quality improvement.

Other researchers define quality as the holistic or system approach of the application of Quality Management methodologies such as six sigma, lean, kaizen, just in time, etc to the process of an organization in order to deliver the right product, at the right time, at the right place and to the right customer [9].

Quality Management may be seen as a management system that aims at increased external and internal customer satisfaction with a reduced amount of resources. This management system consists of the three interdependent elements: values, methodologies, and tools.

The importance of the core values to Quality Management is commonly stressed [12–15]. The core values constitute a very important element as they are the basis of the culture of the organisation and also the basis of goals set by the organisation. However, the naming, formulation, and number of values differ somewhat between different authors. In the Malcolm Baldrige National Quality Award "11 core values and concepts" may be found [16], while Dale discusses "eight key elements", and ISO9000 includes "eight management principles". Since these values are frequently mentioned in the literature describing Quality Management they may be seen as core values of Quality Management [17].

The second element of the quality management system is the set of methodologies, which are ways of working in the organisation to reach the goals. A few examples of methodologies are Six Sigma, Demming Wheel, Taguchi, Kaizen, Lean Manufacturing and JIT.

The third element in the management system consists of tools that are rather concrete and well-defined. The function of the tools in the quality management system is to support the methodologies above. Sometimes these tools have a statistical basis, to support decision-making or facilitate the analysis of data. Some of the frequently used tools are Pareto diagrams, control charts, flowcharts, scatter diagrams, design of experiments etc [17, 18]. These tools are discussed further in the Appendix D

2.2 Evolution of Quality

The evolution of Quality Management may be described in different ways. One common description is made up of four stages that follow each other. These stages are Quality Inspection, Quality Control, Quality Assurance, and Total Quality Management [9, 11].

At the first stage, Quality Inspection, the focus was on the inspection of some critical characteristics of finished products relative to stated requirements. The inspection of products was performed by an inspection department. At the second stage, Quality Control, characteristics of the production process were inspected at some appropriate time interval, and compared to the inherent variation of the process. At this second stage the responsibility for quality was mainly located in the manufacturing and engineering departments. Quality Assurance is the third stage and here the whole production chain, from design to market, and the contribution of all functional departments is considered, in order to prevent failures. This area is closely connected to issues related to routines, responsibilities, and organisation established in standards such as QS9000 and ISO9000. However, top management is only involved to a limited degree. Finally, at the fourth stage, Total Quality Management, everyone in the organisation is considered responsible for quality and top management exercises strong and committed leadership. Total Quality Management further widens the focus and emphasizes the market and customer needs [9, 11].

2.3 Concept From Quality Gurus

From the literature review, there are some people who have had a great influence in the field of Quality Management. These are widely regarded as the Quality Gurus. Some of these are Deming [7] Juran [5], Crosby [6], Feigenbaum [19], and Ishikawa [20]. An extensive review of literature was carried out to identify the concepts of Quality Management from the quality gurus. The following subsections present the main principles and practices of TQM proposed by these quality gurus.

2.3.1 Deming's Approach to Quality

Deming [7] approach to Quality concerns the creation of an organizational system that fosters cooperation and learning. This facilitates the implementation of process management practices, which, in turn, leads to continuous improvement of processes, products, and services. Both continuous improvement and employee fulfillment are critical to customer satisfaction, and ultimately, to firm survival [21]. Deming stressed the responsibilities of top management to take the lead in changing processes and systems. Top management should give employees clear standards for what is considered acceptable work, and provide the methods to achieve it. Deming also emphasized the importance of identification and measurement of customer requirements, creation of supplier partnership, use of functional teams to identify and solve quality problems, enhancement of employee skills, participation of employees, and pursuit of continuous improvement. He advocated for methodological practices, including the use of specific tools and statistical methods in the design, management, and improvement of process, which aim to reduce the inevitable variation that occurs from common causes and special causes in production [7].

2.3.2 Juran's Approach to Quality

Juran believed that main quality problems are due to management rather than workers. Jurans approach is emphasis on team (QC circles and self-managing teams) and project work, which can promote quality improvement, improve communication between management and employees coordination, and improve coordination between employees. He also emphasized the importance of top management commitment and empowerment, participation, recognition and rewards. Juran considered quality management as three basic processes; Quality control, quality improvement, and quality planning. The sporadic problem is detected and acted upon by the process of quality control; The chronic problem requires quality improvement; Such chronic problems are traceable to an inadequate quality planning process. Juran defined four broad categories of quality costs, which can be used to evaluate the firm's costs related to quality [5]. These are:

- Internal failure costs (scrap, rework, failure analysis), associated with defects found prior to transfer of the product to the customer;
- External failure costs (warranty charges, complaint adjustment, returned material, allowances), associated with defects found after the product is shipped to the customer;
- Appraisal costs (incoming, in-process, and final inspection and testing, product quality audits, maintaining accuracy of testing equipment), incurred in determining the degree of conformance to quality requirements;
- Prevention costs (quality planning, new product review, quality audits, supplier quality evaluation, training), incurred in keeping failure and appraisal costs to a minimum.

2.3.3 Crosby's Approach to Quality

Crosby [6] identified important principles and practices for a successful quality improvement program, which include management participation, management responsibility for quality, employee recognition, education, reduction of the cost of quality (prevention costs, appraisal costs, and failure costs), emphasis on prevention rather than after-the-event inspection, doing things right the first time, and zero defects.

2.3.4 Feigenbaum's Approach to Quality

Feigenbaum [19] defined Quality Management as an effective system for integrating the quality development, quality-maintenance, and quality-improvement efforts of the various groups in a firm so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction. He claimed that effective quality management consists of four main stages, described as follows:

- Setting quality standards;
- Appraising conformance to these standards;
- Acting when standards are not met;
- Planning for improvement in these standards.

Feigenbaum emphasized that efforts should be made toward the prevention of poor quality rather than detecting it after the event. According to Feigenbaum, there are two factors affecting product quality: the technology (machines, materials, and processes); and the human (operators, foremen, and other firm personnel). Of these two factors, the human is of greater importance. Feigenbaum considered top management commitment, employee participation, supplier quality management, information system, evaluation, communication, use of quality costs, use of statistical technology to be an essential component of Quality Management. He argued that employees should be rewarded for their quality improvement suggestions.

2.3.5 Ishikawa's Approach to Quality

Ishikawa [20] argued that quality management extends beyond the product and encompasses after-sales service, the quality of management, the quality of individuals and the firm itself. He claimed that the success of a firm is highly dependent on treating quality improvement as a never-ending quest. He emphasized the importance of education, stating that quality begins and ends with education. He has been associated with the development and advocacy of universal education in the seven QC tools: Pareto chart; Cause and effect diagram (Ishikawa diagram); Stratification chart; Scatter diagram; Check sheet; Histogram; and Control chart.

2.3.6 Review of the Quality Gurus' Concepts

After the approaches to Quality Management of the five quality gurus have been reviewed, it has become evident that each has his own distinctive approach. Nevertheless, the principles and practices of Quality Management proposed by these quality gurus do provide the author with a better understanding of the concepts. Although their approaches to quality are not totally the same, they do share some common points which are summarized as follows:

1. It is management's responsibility to provide commitment, leadership, empowerment, encouragement, and the appropriate support to technical and human processes. It is top management's responsibility to determine the environment and framework of operations within a firm. It is imperative that management foster the participation of the employees in quality improvement, and develops a quality

culture by changing perception and attitudes toward quality.

2. It is very important to control the processes and improve quality system and product design. The emphasis is on prevention of product defects, not inspection after the event. Continuous Improvement should be integrated in the quality policy for greatest effectiveness.

3. The importance of employee education and training is emphasized in changing employees' beliefs, behavior, and attitudes; enhancing employees' abilities in carrying out their duties.

4. Employees should be recognized and rewarded for their quality improvement efforts.

5. The strategy, policy, and firm-wide evaluation activities are emphasized.

6. Quality is a systematic firm-wide activity from suppliers to customers. All functions of the organization should be involved in quality improvement efforts.

2.4 Quality Awards

Quality Awards seek to reward and enhance the core values quality management. Worldwide, there are several Quality Awards, such as the Deming Prize in Japan (1951), the European Quality Award in Europe (1994), the Malcolm Baldrige National Quality Award in the United States of America (1999). The Deming Prize was the first quality award and was established by the board of directors of the Japanese Union of Scientists and Engineers in 1951. Its main purpose is to spread the quality gospel by recognizing performance improvements flowing from the successful implementation of firm-wide quality control based on statistical quality control techniques [22]

Each award model is based on a perceived model of TQM. The award models do not focus solely on either product or service perfection or traditional quality management methods, but consider a wide range of management activities, behavior and processes that influence the quality of the final products. They provide a useful audit framework against which firms can evaluate their TQM implementation practices, seek improvement opportunities, and the end results.

In Kenya, there are two quality awards; Kenya Quality Award (KQA), and the Company of the Year Award (COYA).

2.4.1 Kenya Quality Award

This is an annual event that was started in the year 2000 by the Kenya Bureau of Standards (KEBS). KQA combines the North American, European, South African, Indian, Singaporean and Japanese quality award models (which differ in emphasis rather than content), and incorporates local emphasis in accordance with National priorities. The award provides organizations of all types and sizes with a common benchmark for gauging their quality levels and taking action that makes a positive difference, and also finding out how they compare with their peers. The Competition is organized by the Kenya Bureau of Standards (KEBS) within its legal mandate of promoting and facilitating Quality Management for industrial, commercial and trade competitiveness. One of the expectations from the participants is that they will engage in Continuous Improvement. They define this as the ability of the organization to acquire, store and use knowledge for improvement. Continuous Improvement may result to new business opportunities; enhanced organization performance; enhanced value to customers through new and improved products/services; reduced errors, defects, waste and related costs; increased productivity and effectiveness in use of resources.

2.4.2 Company of the Year Award (COYA)

COYA is an yearly award run by Kenya Institute of Management (KIM). COYA seeks to set local benchmarks and develop literature on what is working well in the local companies. The COYA programme enables the Institute to identify individuals and companies that practice professional management in the areas of Quality Management and Innovation and Creativity. Other focus areas for COYA include Financial Planning, Human Resource Management, Environmental Management and Information Management. Using a technically developed management practice assessment tool, COYA enables the companies to identify its key strengths and areas that require improvement.

The broad aims of quality awards are described as follows [22]:

- Increase awareness of TQM because of its important contribution to superior competitiveness;
- Encourage systematic self-assessment against established criteria and market awareness simultaneously;
- Stimulate sharing and dissemination of information on successfully deployed quality strategies and on benefits derived from implementing these strategies;
- Promote understanding of the requirements for the attainment of quality excellence and successful deployment of TQM;
- Encourage firms to introduce a continuous improvement process.

2.5 Quality Management Models

As discussed in section 2.1.3, the second element of a quality management system are the methodologies. These can be viewed as models of quality management and they include ISO Series, TQM, Kaizen, Six Sigma, and JIT among others. Some of them are highlighted below:

2.5.1 ISO 9001 Series

In opinion of many authors, the ISO 9001 describes in most cases the minimal set of processes necessary for delivering quality products and services to customers. In other words, it is often viewed as a necessary minimum, i.e. as the lowest common denominator of an effective quality system. The new ISO 9001 (ISO 9001:2008) is focused on processes. Its eight key management principles are:

1. Customer based organisation;
2. Leadership;
3. Involvement of people;
4. Process approach;
5. System approach to management;
6. Continual improvement;
7. Factual approach to decision making; and
8. Mutual beneficial supplier relationship.

ISO 9001 is meant for organizations that need to show to customers or others that they are able to meet requirements for product development as well as product delivery [23]. This means a great deal to those who supply goods to customers that demand such proof. There are many success stories of both large and small organizations that successfully implemented the new standard. There are many contrasting views about the effectiveness of ISO. Because the new version ISO 9001:2000 is now suitable for any kind of industry or service, it appears a bit 'vague' to many who first come in contact with it. Others argue that ISO does not really contribute to the quality of their products or processes at all [23]. ISO's approach towards quality is based on decreasing iterations and errors by standardizing processes. Quality, however, is not the same as standardization. There are other approaches that could be taken that would in some way or another lead to increased quality in products or processes. For example: focusing on lean manufacturing, firms would attempt to improve their business processes through reducing stock and minimizing waste. Others may find it more important to emphasize environmental issues and aim at cleaner production processes. ISO 9001:2008 is not necessarily the best method. In fact, the ISO standard is a model that can be used to define a method. This is a very important distinction, because the user has responsibility of interpreting and implementing the standard. This has motivated many researchers to define suitable approaches for an ISO implementation. It is in defining procedures that companies define the critical points that contribute to product quality and lead to customer satisfaction. If done correctly, the organization can benefit from ISO's process approach and include the voice of the customer in all process phases. If, however, the organization fails to recognize the quality aspect of this approach, it may end up focusing on formalizing rather than improving our processes. However, it is not an ISO certificate that leads to better products, nor does it contribute to whatever definition you may use for quality. If quality is the organization's goal, the focus should not be on certification, it should be on quality itself. Using ISO, an organization can develop a system that increases awareness of quality issues throughout the organization. Using ISO, the processes that are crucial for customer satisfaction can be improved.

2.5.2 Total Quality Management

TQM may be seen as a business management philosophy with a strong focus on continuous improvement [24] and completely fulfilling customer's requirements with maximum efficiency and effectiveness. As such, TQM affects the company as a whole and the way things are done within the company's lifetime [15]. Brian Rothery [23] illustrates this with an example of a patient in surgery. Rather than checking after he has finished operating whether his patient has survived the operation, the surgeon will be continuously monitoring the patient's well-being. This is the big difference between the ISO and the TQM approach.

However, the focus areas for TQM and ISO similar. The difference is how the models achieve the results in the focus areas. ISO focuses more on standardization and repeatability while TQM focuses on getting the process right every time.

In an organization that is unfamiliar with Quality Management it will be difficult, if not impossible, to implement such a management process. In small and medium sized companies, this is even more complicated due to restricted resources.

2.5.3 Six Sigma

Six Sigma is based on traditional QM methods and tools, in that it strives for fulfillment of customer requirements. There is, however, an important difference: Six Sigma aims to meet the customer requirements fully and profitably. The major difference with TQM, is that Six sigma is characterized as a profit center, not a cost center [24]. This is because Six sigma explicitly considers the company's capital provider by only executing projects that support the core value drivers of the organization. As early as 1930's, quality experts realized that in order to manage quality, we should be able to measure it. Six Sigma recognizes this by focusing on critical parameter management. For core processes parameters are identified that can be measured and monitored. Six Sigma has a strong focus on improvement of profitability. This is realized by striving for 6 σ under the normal distribution in all the processes, products and services. Six Sigma is a disciplined data-driven approach for eliminating defects by by driving towards six standard deviations (6 σ) between the mean and the nearest specification limits. This corresponds to only 3.4 defects per million opportunities (DPMO), which in practice comes down to a virtually error-free process [25]. Large corporations in the US and Europe have successfully implemented Six Sigma into nearly every business activity.

2.6 Review of Quality Tools

Tools and techniques are practical methods, skills, means or mechanisms that can be applied to particular tasks. Among other things they are used to facilitate positive change and improvements. A single tool may be described as a device which has a clear role. It is often narrow in focus and is usually used on its own. Examples of commonly used tools are; cause and effect diagrams, Pareto chart, relationship diagrams, control charts, histograms, and flowcharts. A technique, on the other hand, has a wider application than a tool. This often results in a need for more thought, skill and training to use techniques effectively. Viewed simplistically, techniques can be thought of as a collection of tools. For example, statistical process control (SPC) employs a variety of tools such as charts, graphs and histograms, as well as other statistical methods, all of which are necessary for the effective use of the technique. Examples of techniques are SPC, quality function deployment, failure mode and effects analysis, and design of experiments.

Tools and techniques play a key role in a company-wide approach to continuous improvement. They allow:

- processes to be monitored and evaluated;

- everyone to become involved in the improvement process;
- people to solve their own problems;
- a mindset of continuous improvement to be developed;
- a transfer of experience from quality improvement activities to everyday business operations;
- reinforcement of teamwork through problem-solving.

The number of tools for improvement is continuously increasing as the quest for improved quality and low cost of customers continues to increase. Despite this increase, companies are bound to select only a limited number of these tools that will best suit their business problem at hand to be used.

There are several commercial codes capable of generating most of the discussed tools but the decision as to which tool to use at a particular time/phase is left to the person using the tool. Effective quality management depends on both using individual tools effectively, and knowing what quality tool to use at any particular instance of a quality improvement program. The model discussed in the next chapter assists in deciding which quality tool to use. Some of the tools used for quality improvement are discussed in greater detail in appendix D.

2.7 Causes of Problems in applying Quality Tools

This section reports on a literature review of factors that lead to ineffective application of the quality tools. The purpose was to gain insight into the main reasons why, in some companies, quality tools are not applied at all or not applied successfully. A summary of the findings in each paper is given below. Most of the authors writing on the subject of quality management are agreed that the use and selection of quality management tools and techniques are vital to support and develop the quality improvement process. However, organizations do encounter a range of difficulties in their use and application of quality management tools and techniques.

Lockyer et al. [26] used a postal questionnaire, supplemented with a large program of structured interviews, to discover the barriers to acceptance of statistical methods for quality control in UK manufacturing firms. The tools considered are Sampling and Control Charting (addressed as Statistical Quality Control or SQC). The following problems are reported: Poor application of tools is related to lack of knowledge of tools, caused by lack of training which is, in turn, attributed to lack of support and low priority from management. A customer who demands the application of SQC is reported to be an important influencing factor. Respondents also state that SPC is not applied because it is believed to be inappropriate in their situation. Lack of training is partly attributed to a shortage of training programs offered in education.

Oakland and Sohal [14] performed a survey among UK manufacturing firms concerning usage and barriers to acceptance of production management techniques, including various SPC related techniques. 1500 questionnaires were sent out, 140 were returned. The survey results show that lack of knowledge of tools and the perception that various quality tools are not applicable in a company, are the most important reasons for not making (sufficient) use of tools. Both causes are found to be of more influence in those cases where the level of training is low. Inadequate training is thus concluded to be an important cause of poor application of tools.

Lascelles and Dale [27] address various issues involved in quality improvement, based on a literature review. They relate the problems encountered to various issues in the field of management of organizational change and difficulties in making effective use of the large amount and confusing variety of literature on quality issues. Concerning success factors they conclude that well-known gurus (Crosby, Deming and Juran) have the following points in common: The importance of support and participation of top management; the need for workforce training and education; quality management requires careful planning and a philosophy of company wide involvement; quality improvement programs must represent permanent, ongoing activities.

Modarress and Ansari [28] used a survey among 1000 U.S. firms known to be using quality control techniques (205 were returned). For various departments of the firm, the level of application of both statistical and non-statistical tools, and reasons for slow implementation were assessed. The survey results show that the main area of application of quality tools is still the manufacturing department. The majority of companies do not use quality control techniques in other departments, such as the design department. The main reasons reported for slow implementation are: lack of participation and commitment of both top and middle management. Furthermore, lack of mathematical skills, lack of support from employees, and high costs for implementation are reported. The authors do not suggest any specific solutions for these problems.

Dale and Shaw [11], report on some questions raised by companies in their application of SPC. The authors encountered these questions through their involvement with the introduction of SPC in the automotive industry. Furthermore, they used the results of two SPC questionnaire surveys. They attribute most problems to a lack of understanding of the tools and underlying concepts. This may cause the following problems: people use tools for wrong purposes; tools are not applied because the possible benefits are not understood; tools may not be applied or applied in the wrong way because one does not see how it can be applied in a non-text book situation; tools may also be poorly applied because the role within the total area of quality improvement is not understood. It is suggested that the poor understanding of tools and concepts is caused by the inadequacy of training and education provided on SPC. Furthermore, organizational causes such as lack of training, lack of support from an SPC facilitator, and lack of vision and support from top management are reported to cause the problems observed.

Wozniak [29] reports on causes of poor success related to the way of implementing SPC, based on practical experiences. The problems observed are of an organizational nature: SPC is often upper-management driven, whereby acceptance and understanding by lower level management is not ensured. SPC is seen as the task of one person instead of a team including operators. This causes poor acceptance by and commitment of operators. SPC is presented as a project, rather than a continuous process that should be incorporated in everyone's job, as a result of which attention will fade in time.

Based on a survey and structured interviews among leading UK TQM firms, Mann and Kehoe [30], report on factors affecting the implementation and success of Total Quality Management. In their study, a wide range of quality tools is considered. The most important influencing factors reported were organizational stability and management commitment. They also conclude that the factors differ for various quality tools, e.g. the type of products and production processes influenced the implementation of Statistical Process Control. Since the majority of the quality tools considered were mainly organizational, it is hard to draw conclusions for the more production process oriented tools considered in this thesis.

Does et al. [31] report on experiences in implementing SPC in Dutch industry. They report the following important issues in implementing SPC: It takes several years to implement SPC; time and money must be invested before SPC becomes fully effective throughout the whole organization; constant attention of top management is necessary; SPC requires delegation of tasks, responsibility and authority to the lowest possible level; implementation of SPC must be guided by an expert with thorough understanding of the probabilities and problems of statistics; the organization must be familiar with tackling problems through the use of data; teamwork and project management is essential.

Hagemeyer and Gershenson [32] noted that there were implementation difficulties with many problem-solving programs. The main ones were:

- not knowing what quality tool to use;
- using a quality tool incorrectly;
- using a quality tool for the wrong application;
- not knowing when to use a quality tool; and
- not using one of the quality tools when one is needed.

The author proposes that Information Technology (IT) can be used to to solve some of the problems highlighted above. A literature review on the integration of IT with quality management was thus carried out.

2.8 Integration of IT with Quality Management

Literature on integration of IT and Quality Management is rare. The literature reviewed below, however, indicates successful application of the available commercial packages to solve quality programs.

Some authors consider that IT is an enabler of Quality Management. For example, Zadrozny and Ferrazzi [33] claim that the information systems function plays a key role in the TQM initiative through the strategic, human resources, and technology areas. Murray [34] claims that IT is increasingly being used to measure, understand, and improve an organisation's level of sustainable quality. Clearly, IT can help to facilitate the application of statistical process control (SPC), design of experiments, failure mode and effects analysis (FMEA), quality function deployment (QFD) and self assessment against a business excellence model. IT can be vital in the development of real-time collection of data in terms of customer satisfaction, internal process controls, critical business systems, and other measurement systems which are necessary to support TQM.

Konstadt [35] argues that sophisticated communications and computational tools and data storage systems are the key to success with TQM. He goes on to make the point that IT can be an enabler in the drive for continuous improvement, even when the basic processes and management worker relationships remain traditional. IT is also useful in design of experiments [36], Failure Mode and Effect Analysis (FMEA) [37] and Quality Function Deployment (QFD) [38, 39]. In all these cases, IT does not change the way to apply these quality tools and techniques, but it helps to facilitate a more complete use of all their possibilities and facilitates application. IT has been found useful in the task of process flow management. It assists the maintenance function through the use of automated systems to detect the need for machine maintenance and diagnose what needs to be done; this can be carried out at a location remote from the machine [40, 41].

Automation helps to reduce process variance, because machines usually demonstrate less variability than workers and increases the speed of production processes with a significant quality enhancement [42]. However, this does not mean that the need for quality management becomes less; on the contrary, automated machines only work with quality products [43]. Both electronic detection and signalling devices also help to reduce process variance. SPC may be facilitated, through the automated measurement of product and process parameters and the registration and processing of data [44]. Gong et al. [45] proposed a procedure for combining an on-line sensor and a control chart to improve statistical process control decisions. The manner in which IT can help in different tasks, such as the determination and use of quality costs, feedback of quality data to employees and managers for problem solving, providing timely quality performance measurements, and improving the availability of quality-related data is an issue which has started to surface in the literature but needs further exploration.

Another way in which IT can be used to assist in Quality Management is in tool selection. There are many commercial codes capable of generating most of the tools described above, but the decision as to which tool to use at a particular phase is left to the person using the tool. Effective Quality Management depends on both using individual tools effectively and knowing what quality tool to use at any particular instance of quality improvement program. There are instructions and web sites where various tools and techniques are described. However, a code that is able to recommend a tool to use in any given situation based on answers to simple questions would be more useful.

The model, described in section 3.2, assists in deciding which quality tool to use, using a classification scheme that selects tools depending on their attributes.

CHAPTER THREE

3.0 METHODOLOGY

In this chapter, the research design for the survey and model development for the computer code are described. In research design, the research hypothesis are derived, and the procedures followed in developing the questionnaire are described. In model development, the knowledge base, inference engine and user interface development methodologies are explained.

3.1 Research Design for the Survey

3.1.1 Research Hypotheses

The research hypotheses were developed to correspond to the research objectives. Five hypotheses relating to the general status of CI in Kenya were proposed, and four hypotheses relating to comparative CI implementation within manufacturing sector were proposed.

3.1.1.1 Hypotheses related to general implementation of Continuous Improvement

1. That manufacturing firms in Kenya implement Quality Management programs
2. That manufacturers in Kenya pursue Quality Management best practices
3. Manufacturing firms in Kenya use traditional quality management tools
4. Manufacturing firms apply new quality management tools in their operations
5. That manufacturing firms in Kenya can identify the main areas of quality improvement that would be beneficial to the organization.

3.1.1.2 Hypothesis related to comparative implementation of CI within the Kenyan manufacturing sectors

1. Large Scale organization practice Continuous Improvement in their operations
2. Technology-intensive manufacturers practice CI in their operations
3. Manufacturers targeting international markets practice CI in their operations
4. Older manufacturing organization practice CI in their operations

3.1.2 Procedures followed in the development of the instrument

3.1.2.1 Compilation of items

A literature review enabled the researcher to compile questions suitable to the problem. The questions compiled with the help of a literature review were categorized into the following broad areas;

- Participation in Quality awards
- Quality Management programs implementation level
- Employee training on Quality Management
- Quality Improvement practices
- Usage of traditional and advanced tools
- Areas of improvement

3.1.2.2 Description of the instrument

The draft instrument was developed from the items categorized above. It was decided that the draft instrument would take the form of a self-report instrument. A self-report instrument allows anonymity and more candid responses can thus be obtained [46]. This type of questionnaire was also regarded as the most appropriate for scoring purposes. The questionnaire implements a Likert-type response scale. The respondents were asked to respond by indicating their degree of agreement or disagreement. The instrument is formatted into a series of short statements. To prevent mis-interpretation of the questions, short explanations were offered where deemed necessary.

The Table 3.1 shows the items included in the final questionnaire and the rationale for including them.

3.1.2.3 Validity and Reliability of the questionnaire

Validity of the questionnaire is a very important aspect of the research. Two aspects of validity were considered; content validity and face validity [47].

Content validity refers to whether the items are adequate for measuring what they are supposed to measure and whether they constitute a representative sample of the behavior domain under investigation.

Face validity refers to the extent which the questions, on the face thereof, measure the construct it is supposed to measure (e.g. usage of QM tools, implementation of QM programs) [47]

Both types of validity are determined by the judgement of the experts. After implementing the suggestions of the project supervisors, the draft instrument, and an attached

Table 3.1: Items in the questionnaire and the rationale

Item in Questionnaire	*Rationale*
Instructions	
• Introduction	• Outlines the nature of the study and the general structure of the questionnaire
• Benefits of the study	• Outlines the benefits of the study
• Confidentiality	• Affirmation of confidentiality
• Filling questionnaire	• Gives information as to who should ideally respond to the questionnaire
• Follow-up interviews	• Requests for an opportunity to participate in the follow–up case study
• Contact person	• Gives the contacts of the researcher
General Company Information	
• Number of employees	• This is a measure to assist in classifying the organization as either small, medium or large
• Year of establishment	• Will establish a correlation between quality management maturity and length of operation of the organization
• Mode of manufacture	• Will seek to find correlation between CI implementation and mode of manufacture
• Target market	• Find correlation between target market (local or foreign) and CI implementation
Current Implementation of CI	
• Participation in Quality awards	• Participation implies implementation of highest level of QM.
• QM programs implementation	• Studies the extent of implementation of QM programs to give an indication as to the status
• Employee QM training	• Measures frequency of employee training, and management commitment.
• Quality Management practices	• Measures actual activities and constructs of quality management
Usage of traditional and advanced tools	
• Applicability and effectiveness	• Extent of tools use and the perceived effectiveness understanding is an indicator of quality maturity
Areas of Improvement	
• Sources of defects	• Determines the identified local quality challenges or problems
• Best practices	• Determines desired best quality practices
Research Interest	
• Willingness to be a case study	• Requests for an opportunity to carry out a case study in the organization

evaluation sheet, was given to two practicing Quality Management experts to obtain their comments on content validity and face validity. Since the recommended maximum time to answer a questionnaire is 30 mins [48], the time involved in answering each question and the level of difficulty for each question was noted by the two experts. The two experts concluded that the questionnaire was valid for testing the hypothesis and was within the required time limit(19 minutes and 21 minutes.

3.1.3 The Survey

The questionnaire was mailed to 174 manufacturing firms in Kenya. Various Databases were used to draw the sample. The companies were selected randomly in the KAM, KIRDI,MSED and Postel databases, in accordance with the rules for carrying out a survey. The databases used and provision in the databases is shown in Table 3.2. After mailing the questionnaire, follow up interviews were conducted due to a low response rate.

Table 3.2: Surveyed Companies Sample Source

Source	***Provision***	***Companies***
1. KAM directory	Name, Sector, Postal address, email address, phone number	85
2. Postel directory	Name, address, products,email	42
3. KIRDI directory	Name, product, plant size, year established, capacity, postal address, phone number	36
4. MSED Database	Name, address, products, email address	11
Total		**174**

3.1.4 Data Analysis

In analyzing the data, the Friedman Tests was used. The Friedman test is an extension of the Wilcoxon test. Friedman test allows for the analysis of repeated-measures data if participants are assessed on two or more occasions or conditions or to matched-subjects data if participants are matched in pairs, triplets, or in some greater number. The

Friedman test is applicable to problems with repeated-measures designs or matched-subjects designs. With repeated-measures designs, each participant has scores on K variables, the score obtained on each of the K occasions or conditions.

A researcher is interested in determining if subjects changed significantly across occasions (or conditions). For a matched-subjects design, participants are matched in sets of K participants, and each participant in a set is assessed once on a measure. Each set of participants has scores on K variables, the scores obtained on the measure by the participants within a set. If the independent variable has only two occasions or conditions, no additional significance tests need to be conducted beyond the Friedman test. However, if a factor has more than two occasions or conditions and the overall test is significant, follow-up tests are usually conducted.

For the Friedman test, the dependent variable must be measured on at least an ordinal scale, and the null hypothesis states that the population medians are equal for the K levels of a factor. The parametric alternative to the Friedman test is the one-way repeated-measures analysis of variance (RM-ANOVA). For either test, analyses involve a factor with K levels, and we are interested in evaluating whether scores differ significantly across the levels of the factor. The tests take into account the dependency among scores introduced by the repeated-measures or matched-subjects characteristics of the design.

Kendall's coefficient of concordance (Kendall's W), is calculated as a strength-of-relationship index. The coefficient of concordance ranges from 0 to 1, with higher values indicating a stronger relationship. A level of significance p, the probability that the observed difference between conditions is due to random variability, is also calculated. If this probability is low enough (typically $p < 0.05$ or $p < 0.01$), we can reject the null hypothesis, in favour of the research hypothesis.

Assumptions Underlying a Friedman Test

Assumption 1: Each set of K observations must represent a random sample from a population and must be independent of every other set of K observations. If the data are from a repeated-measures design, the scores for each participant must be independent of the scores from any other participant. If the data are from a matched subjects design, the sets of scores from any matched set of participants must be independent of the scores of any other matched set of participants. If the independence assumption is violated, the test is likely to yield inaccurate results. It should be noted that the analysis permits dependency among scores within a set.

Assumption 2: The Chi-Square values for the Friedman test yield relatively accurate results to the extent that the sample size is large. The results for the tests should be fairly accurate if the sample size is 30 or greater.

Assumption 3: The Distribution of the differences scores between any pair of levels is continuous and symmetrical in the population. This assumption is required to avoid ties and to ensure that the test evaluates difference in medians rather than other characteristics of the distribution.

3.2 Model Development

3.2.1 Introduction

The proposed model utilizes Artificial Intelligence (AI), which are computer programming techniques finding applications extensively in solving problems in areas such as industrial process control, medicine, geology, diagnostics and many other areas. More specifically, the model can be categorized as an Expert System (ES), which is a computer system that is designed to implant expertise of a human being in a certain domain. In this case, the domain is Quality Management, and the expertise is derived from the extensive literature review. The basic elements of an ES program are;

- Knowledge base or Data base
- Inference Engine
- User Interface

3.2.2 Knowledge Base

The representation of a knowledge base is the core of an ES. The knowledge is organized in a form of IFTHEN rule connected by LOGICAL AND, OR and NOT operations for drawing the inference or conclusions. The Knowledge base of this program comprises of past research on problem-solving tools and their areas of application. Several classification tools that allow the user to identify correct quality tool at the proper time have been proposed [11]. In 2006, Catherine Hegemeyer et al [32]proposed and validated a classification scheme based on attributes of the quality tools. The attributes included in the scheme are:

- general categorizations
- Inputs to the tool
- Outputs of the tool

3.2.2.1 General Categorizations

These are further subdivided into:

- Improvement phase that the tool is used; PDCA / DMAIC

- Type of tool; clerical, analytical, or statistical
- Required skill of user: novice, intermediate, advanced

3.2.2.2 Inputs to the tool

These include:

- Quality Improvement phase; Design, Measure, Analyze, Improve or Control
- What is needed for tool use; process knowledge, data collection, numerical analysis
- What the tool works with; ideas, numbers

3.2.2.3 Outputs of the tool

These include:

- Tool function; generate, group, decide, implements, counts
- Tool classification; document, tool, technique
- Physical outcome

Utilizing this scheme, a database was created to drive the computer based model. Each tool was analyzed for its characteristics based on the above categories and that formed the corresponding entries in the database. These entries are shown in Appendix B.

3.2.3 Inference Engine

This is the control software that draws conclusions by testing the knowledge base. It utilizes an algorithm that infers the tool required from the attributes in the knowledge base. The attributes were structured as open ended questions and statements requiring the response of the user. The inference engine was programmed using Visual Basic 6.0. The Visual Basic Programming language was chosen because of its versatility in creating user friendly interfaces.

3.2.4 User Interface

The user interface is very important because usually the user is unskilled or semi skilled person who may not have much knowledge of the problem he/she is trying to solve. On the interface were pre-programmed questions that are structured to identify the attributes of the tool. Multiple choice answers to the questions were provided in the drop- down menus on the interface, for ease of selection. This also prevents errors in querying the database. Help messages are also provided on the screen.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS FOR THE SURVEY

4.1 Introduction

This chapter presents the survey findings. The survey sought to investigate the status and the level of usage of Continuous Improvement(CI)in Small, Medium and Large Scale manufactures in Kenya. The study targeted a sample of 174 respondents from the manufacturing sector. The study used a structured questionnaire to collect the primary data. Follow up interviews were conducted. Of the 174 questionnaires, 58 were returned and found to be usable, representing a 33% response rate. The data was cleaned, coded and entered into SPSS software to build a database that was subjected to data analysis. Descriptive statistics such as percentages, pie charts, and graphs were used to describe, analyze and present the study findings, which follow.

4.2 General company information

The following are the study findings regarding the general company information for the respondents. This included the size of the firm, when it was established, the manufacturing sector, mode of manufacture and the target market [4]. Tables 4.1, 4.2, 4.3, 4.4, and 4.5 summarizes the attributes of the respondents. The classification of the respondents is based on classification used by Kenya Association of Manufacturers surveys [4].

Table 4.1: Company size

Serial no.	Size of the company	No of respondents	Percentage
1	Small scale	24	41.4
2	Medium scale	26	44.8
3	Large scale	8	13.8

Table 4.2: Number of years in business

Serial no.	Years in business	No of respondents	Percentage
1	Less than 15	17	29.3
2	16 - 35	32	55.2
3	More than 35	9	15.5

Table 4.3: Specific manufacturing sector

Serial no.	Manufacturing sector	No of respondents	Percentage
1	Chemical and Allied	4	6.9
2	Energy, Electrical and Electronics	4	6.9
3	Food and beverage	12	20.7
4	Leather and Footwear	4	6.9
5	Metal and Allied	12	20.7
6	Mining and Construction	4	6.9
7	Motor vehicle and Accessories	5	8.6
8	Paper and Board	4	6.9
9	Plastic and Rubber	4	6.9
10	Textiles and Apparels	3	5.2
11	Timber, Wood and Furniture	2	3.4

Table 4.4: Mode of manufacture

Serial no.	Mode	No of respondents	Percentage
1	Labor intensive	42	72.4
2	Technology intensive	16	27.6

Table 4.5: Target market

Serial no.	Target Maket	No of respondents	Percentage
1	Only domestic	26	44.8
2	Domestic market more than international market	16	27.6
3	Domestic market equal to international market	16	27.6

4.3 General Hypothesis testing

4.3.1 Implementation of Quality Management

Implementation of quality management philosophies has a great bearing on the application of tools and equipments. Kaizen quality improvement program is the most implemented quality management philosophy in the industry. Majority of respondents that accounted for 33.3% replied that their firms had plans to implement the Kaizen program, and 28.1% had fully implemented it in their firm. 29.8% of the firms had partially implemented, while 8.8% reported that they had not implemented and had no plan to implement Kaizen in their organizations.

36.8% of the firms had not implemented TQM, 7% had no intention of implementing TQM, 24.6% had fully implemented TQM while 31.6% of the firms were in the process of implementation.

14% of the respondents indicated that they were ISO certified, 23.9% were in the process of ISO certification and the firms had partially implemented it, while 32.3% had plans for ISO certification, 29.8% indicated that there was no plan for ISO Certification. Follow up interviews indicated that the length of the process and the associated costs were the main hindrance to the organization's pursuit for ISO certification.

47.4% of the firms had plans to implement the statistical quality control in their firms, and 12.3% of the firms had fully implemented them, while 20.5% of the firms had partially implemented the statistical quality controls, and 19.8% of the firms had no plans for implementation.

Six sigma was the Quality Program least implemented, with 67.9% of the firms indicating that they did not plan to implement Six Sigma, and 30% of the firms claimed there were plans for implementation. Only 1.8% of the firms had partially implemented Six Sigma.

No firm had fully implemented Six Sigma.

From the mean ranks, the QM philosophies that were adopted by most firms were Kaizen, followed by TQM program, ISO Certification, Six Sigma in that order. In general, the hypothesis that manufacturing organizations in Kenya practice Quality Management Philosophies was found to be valid as shown in Table 4.6.

Table 4.6: Adoption of Quality Management Philosophies

Serial no.	Philosophy	1	2	3	4	Mean	Standard deviation
1	TQM Program	7.0	36.8	31.6	24.6	2.8070	0.97172
2	ISO Certification	29.8	32.3	23.9	14.0	2.2368	1.04414
3	Kaizen	8.8	33.3	29.8	28.1	2.8596	0.98992
4	Statistical quality control	19.8	47.4	20.5	12.3	2.5614	0.90667
5	Six Sigma	67.9	40.4	1.8	0.0	1.4386	0.53511

KEY

1 no. there is no plan for implementation.

2 no. but there is a plan for implementation.

3 yes. It is partially implemented.

4 yes. It is fully implemented.

4.3.2 Status of the organization with regard to the practices that pertain to quality management

In order for an organization to produce quality goods and services, there are some key practices that should be evident in the firm's operations. These include defined processes, reliable facilities (equipments),and up-to-date documentation among others. These issues were tested and the respondents were requested to rank them on a four point Likert scale, (1 for strongly disagree.......4 for strongly agree).

From the tests done, a Friedman ANOVA test revealed that X^2 (11)= 7.70, the Kendall's coefficient of concordance is 0.12 and $p < 0.01$. From this information, it is clear that most of the respondents agreed that the practices that pertain to quality management were practiced to some extent in these manufacturing firms. This was also shown by the means scores, which ranged between 2.44 and 2.75 as indicated in Table 4.7. This in general indicates quality awareness amongst the Kenyan manufacturers. From the mean rank, it is clear that human qualities associated with quality management scored least; workforce flexibility, and shop floor idea generation. However, the organizations are required to be stronger in improving human qualities and ensure their participation, create a conducive work culture for quality improvement.

Table 4.7: Quality management practices status in organizations

Serial no.	Type of practice	Mean rank	Mean	Std deviation	X^2 Value
1	Clear documentation	6.30	2.5789	1.0168	3.421
2	Need for continual change	7.02	2.7544	0.9118	13.246
3	Facility reliability	6.77	2.6842	1.0549	4.965
4	Commitment to CI	6.89	2.6842	1.0882	1.877
5	Workforce is flexible	5.85	2.4386	0.9452	9.456
6	Commitment to training	6.46	2.6316	0.8990	12.544
7	Shortest throughput time	6.49	2.6667	1.0408	2.719
8	Reduction of costs	6.73	2.7018	1.1796	3.281
9	Lead times are measurable	6.86	2.7132	1.1175	1.896
10	Waste/misuse removed	6.26	2.5614	1.0859	0.614
11	Shop floor ideas	6.13	2.5439	1.1030	1.035
12	Satisfactory inventory	6.24	2.5263	1.0539	1.737

4.3.3 Applicability of traditional quality management tools and techniques

Traditional quality tools and techniques are quite useful in any organization be it small or large. The hypothesis assumed that these traditional tools and techniques are used by the manufacturing firms in Kenya. The data was provided on a five-point scale (0 - 4). A Friedman ANOVA test revealed that X^2 (12) = 8.485, the Kendall's coefficient of concordance is 0.12 and $p < 0.01$. From the above-derived information, it is apparent that these tools are in use in the manufacturing firms in Kenya. The most commonly used tools are brainstorming, followed by check sheets and flow charts as indicated by the mean score in Table 4.8. All the tools are used to some extent in the Kenyan Manufacturing sector.

Table 4.8: Applicability of traditional quality management tools and techniques

Serial no.	Quality tools	Mean rank	Mean	Std deviation	X^2 Value
1	Scatter diagram	6.32	2.1053	1.34542	2.912
2	Pareto diagram	6.39	2.1579	1.19208	11.684
3	Cause and effect diagram	7.12	2.3860	1.19155	11.684
4	Flow charts	7.31	2.3860	1.19155	11.684
5	Check sheets	7.43	2.3860	1.14571	11.158
6	Histogram	7.19	2.2807	1.20645	7.649
7	Brainstorming	7.52	2.4211	1.20930	8.526
8	SPC control charts	7.17	2.3158	1.33841	5.895
9	Design of experiments	6.72	1.2105	1.43598	1.684
10	FMEA	6.80	1.2281	1.25382	5.719
11	Capability analysis	5.46	0.3684	1.33137	6.947
12	Mistake proofing	6.79	1.2456	1.24328	7.123
13	Box plot	6.82	1.2105	1.34612	2.035
14	Average	7.00	2.2848	1.2639	7.285

4.3.4 Applicability of new quality management tools and techniques

How some advanced (new) quality management tools such as affinity diagrams, interrelationship diagram, tree diagram, prioritizaion matrix, matrix diagram, process decision program chart and activity network diagram as a whole are applicable in the SMEs and their effectiveness was also checked on a five-point scale and analyzed.These tools appear not to be used in any manufacturing organization in Kenya. This might be attributed to a general lack of awareness. In addition, these tools are more of management tools, rather than shop floor tools. This might indicate that the level of quality management to be at the shop floor level, with the management providing the requisite support but not using any tools themselves.

4.3.5 Areas of improvement that would be beneficial to the company

According to the findings on the areas that needed improvement, which would be beneficial to the company, the study, revealed that machinery needed more improvements as it ranked first followed by processes as shown in Table 4.9. Machinery and Process improvement are the two areas that can be improved by the application of quality tools. This indicates that the organizations are generally aware of the problem, but lack the knowledge to solve the problem. This is collaborated by the earlier research where there had been indications that the many organizations are unaware of the benefits they can accrue from the use of quality tools [32].

Table 4.9: Areas of Improvement That Would Be Beneficial To the Company

Serial no.	Tools	Mean rank	Mean	Std deviation	Median	X^2 Value
1	Raw Material	2.46	1.4912	0.94723	1.00	21.667
2	Operators	2.26	1.3860	1.03085	1.00	3.000
3	Processes	2.61	1.5965	0.97942	2.00	9.316
4	Machinery	2.66	1.6140	1.06493	2.00	1.737

4.4 Hypothesis related to comparative implementation of CI within the Kenyan manufacturing organizations

- Large Scale organization practice Continuous Improvement in their operations

- Technology-intensive manufacturers practice CI in their operations
- Manufacturers targeting international markets practice CI in their operations
- Older manufacturing organization practice CI in their operations

In investigating the validity of these hypotheses, the respondents' responses on their implementation of Quality Management, their awareness of the quality management practices and the application of quality management tools in their operations were analyzed. In each of these cases the data was split to indicate the following subcategories; large, medium, and small scale manufacturers; Technology intensive and labor intensive manufacturers; International and local manufacturers; and age bands for the manufacturers. The data was then analyzed to test the validity of the above hypotheses.

4.4.1 Comparative hypothesis 1: Large scale organization practice Continuous Improvement in their operations

4.4.1.1 Adoption of Quality Management Principles

Looking at the mean, standard deviation and the X^2 values, it is evident that the large scale firms practice quality management more than the medium scale and small scale firms as shown in Table 4.10. A Friedman ANOVA test revealed an X^2 (4) = 53.175, the Kendall's coefficient of concordance is 0.554 and $p < 0.01$. Medium scale firms adopt quality management philosophies to a moderate extent as shown by a Friedman ANOVA test that revealed that X^2 (4) = 48.362, the Kendall's coefficient of concordance is 0.465 and $p < 0.01$. Small scale firms have adopted quality management philosophies least in their operations as shown by a Friedman ANOVA test that revealed an X^2 (4) = 8.583, the Kendall's coefficient of concordance is 0.307 and $p < 0.01$. This test revealed that large scale firms adopt quality management philosophies more than medium scale and small scale firms. This view is reinforced by an earlier informal survey carried out by the researcher in the preliminary stages of the research where the researcher visited several umbrella bodies. These include Kenya Industrial Research Development Institute (KIRDI), Kenya Association of Manufacturers (KAM) and Federation of Kenya Employers (FKE). The researcher conducted interviews with the industry experts who indicated that the level of Quality Management practices among the small scale manufacturers was much less as compared to the Large Scale manufacturers.

Table 4.10: Adoption of Quality Management Philosophies

Serial no.	QM Philosophy	Large scale			Medium scale			Small scale		
		MR	M	SD	MR	M	SD	MR	M	SD
1	TQM Program	3.83	3.00	1.02	2.93	2.81	0.53	3.52	2.57	1.06
2	ISO Certification	3.69	2.92	0.97	3.29	2.73	1.11	3.50	2.71	0.96
3	Quality activities	3.27	2.71	0.95	3.00	2.81	1.13	3.58	2.57	1.13
4	Statistical quality control	3.93	3.00	0.58	2.92	2.46	0.88	3.08	2.54	0.99
5	Six Sigma	1.86	1.86	0.69	1.33	1.38	0.50	1.29	1.38	0.49

4.4.1.2 Understanding of the basic quality management principles

From the mean scores, large scale firms indicated the greatest understanding of the basic quality management principles. This was shown by a mean score of 2.65. A Friedman ANOVA test generates X^2 (11) = 11.078, the Kendall's coefficient of concordance is 0.042 and $p < 0.01$. Medium scale firms understood the basic quality management principles as shown by a mean score of 2.61. A Friedman ANOVA test revealed X^2 (11) = 15.2, the Kendall's coefficient of concordance is 0.053 and $p < 0.01$. Small scale firms also understood the basic quality management principles by an average score of 2.54 as shown in Table 4.11. A Friedman ANOVA test revealed X^2 (11) = 18.135, the Kendall's coefficient of concordance is 0.236 and $p < 0.01$.

Table 4.11: Understanding of the basic quality management principles

Serial no.	Principle	Large scale			Medium scale			Small scale		
		MR	M	SD	MR	M	SD	MR	M	SD
1	Clear documentation	5.85	2.50	1.06	6.62	2.65	1.02	6.64	2.57	0.98
2	Need for continual change	6.02	2.58	1.06	8.25	3.00	0.69	5.86	2.43	0.98
3	Facility reliability	5.65	2.46	1.10	7.31	2.81	0.98	8.64	3.00	1.15
4	Commitment to CI	7.65	2.88	1.08	6.87	2.65	1.09	4.43	2.14	1.07
5	Workforce is flexibility	6.27	2.54	1.06	5.94	2.46	0.86	4.07	2.00	0.82
6	Commitment to training	7.38	2.88	0.90	6.06	2.54	0.90	4.79	2.14	0.69
7	Shortest throughput time	7.31	2.92	1.10	5.88	2.50	0.99	5.93	2.43	0.98
8	Reduction of costs	6.90	2.79	1.28	6.58	2.65	1.13	6.71	2.57	1.13
9	Lead times are measurable	6.50	2.58	1.10	6.75	2.73	1.15	8.50	3.00	1.15
10	Waste / misuse removed	6.42	2.63	1.21	5.54	2.38	1.06	8.43	3.00	0.58
11	Shop floor ideas	5.96	2.54	1.22	5.96	2.50	1.10	7.36	2.71	0.76
12	Satisfactory inventory	6.10	2.54	1.10	6.25	2.50	1.07	6.64	2.57	0.98
13	Average		2.65			2.61			2.55	

4.4.1.3 Application of quality management tools

Application of quality management tools facilitates the objective decision making. All these tools might not be suitable for small scale firms but manufacturing organizations can use them as part of their decision support system. From the study, both small scale firms and the medium scale firms used the quality management tools to a moderate extent as shown by Friedman ANOVA test X^2 (12) = 8.287, the Kendall's coefficient of concordance is 0.029 and $p < 0.01$, and the Friedman ANOVA test X^2 (12) = 11.751, the Kendall's coefficient of concordance is 0.038 and $p < 0.01$ respectively. Large scale firms used the quality management tools more than the small scale and medium scale organizations as shown in Table 4.12. A Friedman ANOVA test generates X^2 (12) = 19.127, the Kendall's coefficient of concordance is 0.228 and $p < 0.01$

Table 4.12: Application of quality management tools

Serial no.	Philosophy	Large scale			Medium scale			Small scale		
		MR	M	SD	MR	M	SD	MR	M	SD
1	Pareto diagram	6.35	2.13	1.51	6.90	2.15	1.38	4.00	1.86	0.38
2	Cause and effect diagram	6.42	2.17	1.34	6.90	2.15	1.12	4.43	2.14	1.07
3	Brainstorming	7.52	2.46	1.25	6.85	2.27	1.15	6.79	2.57	1.27
4	Flow charts	6.96	2.25	1.36	7.17	2.35	1.02	9.00	3.00	1.15
5	Check sheets	6.90	2.29	1.30	7.52	2.35	1.06	8.93	2.86	0.9
6	Histogram	7.06	2.29	1.40	7.23	2.23	1.07	7.29	2.43	1.13
7	SPC control charts	6.48	2.21	1.28	8.23	2.54	1.14	8.43	2.71	1.25
8	Scatter diagram	6.54	2.21	1.61	7.60	2.31	1.19	7.71	2.71	0.76
9	Design of experiments	6.13	2.08	1.47	6.81	2.15	1.52	8.43	2.86	0.90
10	FMEA	7.69	2.46	1.25	6.27	2.00	1.36	5.71	2.29	0.76
11	Capability analysis	7.81	2.46	1.18	7.62	2.31	1.57	5.64	2.29	0.95
12	Mistake proofing	7.21	2.29	1.40	6.33	2.12	1.21	7.07	2.57	0.77
13	Box plot	7.94	2.50	1.29	5.58	1.81	1.37	7.57	2.71	1.11

4.4.2 Comparative Hypothesis 2: Technology-intensive manufacturers practice CI in their operations

4.4.2.1 Adoption of Quality Management Philosophies

Technology Intensive manufacturers adopt quality management philosophies more than labor intensive manufacturers as shown by the higher mean ranks. A Friedman ANOVA test revealed X^2 (4) = 76.704, the Kendall's coefficient of concordance is 0.457 and $p < 0.01$. This is contrary to what would be expected as the more automated manufacturing process is less prone to non conformities. Labor intensive manufacturers adopt quality management philosophies to a moderate extent as shown by a lower average score of 2.47 in Table 4.13. A Friedman ANOVA test X^2 (4) = 28.356, the Kendall's coefficient of concordance is 0.473 and $p < 0.01$.

Table 4.13: Adoption of Quality Management Philosophies

Serial no.	Philosophy	Technology Intensive			Labor Intensive		
		MR	M	SD	MR	M	SD
1	TQM program	3.65	2.90	1.05	3.37	2.73	0.80
2	ISO certification	3.65	2.86	0.98	3.27	2.67	0.98
3	Quality activities	3.29	2.69	1.09	3.63	2.87	0.92
4	Statistical quality control	3.01	2.50	0.97	3.40	2.73	0.70
5	Six Sigma	1.39	1.43	0.55	1.33	1.47	0.52
6	Average		2.4762			2.4933	

4.4.2.2 Understanding of the basic quality management principles

On the understanding of the basic quality management principles, the study revealed that Technology intensive manufacturers understands the basic quality management tools as shown by a higher average score of 2.63. A Friedman ANOVA test revealed X^2 (11) = 4.082, the Kendall's coefficient of concordance is 0.009 and $p < 0.01$. Labour intensive manufacturers also understand basic quality principles as indicated by an average score of 2.57. A Friedman ANOVA test revealed X^2 (11) = 8.456, the Kendall's coefficient of concordance is 0.051 and $p < 0.01$. The study therefore revealed that both labour intensive manufacturers and technology intensive manufacturers, understand the underlying basic quality management principles as shown in Table 4.14. However the level of understanding is slightly higher in the technology intensive manufacturers. This is indicated by the slightly higher score in the average scores.

4.4.2.3 Application of Quality management tools

On the application of quality management tools, labour intensive manufacturers applied the quality management tools for decision making to a moderate extent as shown by an average score of 2.3. A Friedman ANOVA test revealed X^2 (12) = 3.418, the Kendall's

Table 4.14: Understanding of the basic quality management principles

Serial no.	Principle	Labour intensive			Technology intensive		
		MR	M	SD	MR	M	SD
1	Clear documentation	6.49	2.64	1.10	5.77	2.40	0.74
2	Need for continual change	6.94	2.76	0.93	7.23	2.73	0.88
3	Facility reliability	6.58	2.64	1.06	7.30	2.80	1.08
4	Commitment to CI	7.04	2.71	1.04	6.50	2.60	1.24
5	Workforce is flexibility	6.06	2.50	0.97	5.27	2.27	0.88
6	Commitment to training	6.51	2.67	0.93	6.30	2.53	0.83
7	Shortest throughput time	6.23	2.62	1.06	7.23	2.80	1.01
8	Reduction of costs	6.61	2.69	1.20	7.07	2.73	1.16
9	Lead times are measurable	6.71	2.69	1.07	7.27	2.7333	1.28
10	Waste / misuse removed	6.19	2.55	1.12	6.47	2.60	1.06
11	Shop floor ideas	6.18	2.60	1.11	6.00	2.40	1.12
12	Satisfactory inventory	6.46	2.60	1.06	5.60	2.33	1.05
13	Average		2.6389			2.5778	

coefficient of concordance is 0.007 and $p < 0.01$. Technology intensive manufacturers also applied the quality management tools to a moderate extent as shown by a mean score of 2.23. A Friedman ANOVA test revealed X^2 (12) = 8.581, the Kendall's coefficient of concordance is 0.048 and $p < 0.01$. This can be explained by the fact that labor intensive manufacturers have more opportunities to use the quality tools by the very nature of their operations as shown in Table 4.15.

4.4.3 Comparative Hypothesis 3: Manufacturers targeting international markets practice CI in their operations

4.4.3.1 Adoption of Quality Management Philosophies

On the adoption of quality management philosophies, the study found that manufacturers targeting domestic market adopt quality management philosophies to a moderate extent as indicated by an average score of 2.46. A Friedman ANOVA test revealed X^2

Table 4.15: Understanding of the basic quality management principles

Serial no.	Tool	Labour intensive			Technology intensive		
		MR	M	SD	MR	M	SD
1	Pareto diagram	6.37	2.12	1.40	6.17	2.07	1.22
2	Cause effect diagram	6.71	2.21	1.26	5.50	2.00	1.00
3	Brainstorming	7.14	2.40	1.21	7.07	2.33	1.175
4	Flow charts	7.17	2.36	1.19	7.70	2.47	1.25
5	Check sheets	7.19	2.38	1.15	8.10	2.40	1.18
6	Histogram	7.06	2.26	1.25	7.47	2.33	1.11
7	SPC control charts	7.39	2.43	1.19	7.87	2.40	1.30
8	Scatter diagram	7.04	2.31	1.46	7.53	2.33	0.98
9	Design of experiments	6.86	2.29	1.50	6.33	2.00	1.25
10	FMEA	6.79	2.24	1.25	6.83	2.20	1.32
11	Capability analysis	7.45	2.36	1.40	7.47	2.40	1.18
12	Mistake proofing	6.96	2.31	1.24	6.30	2.07	1.28
13	Box plot	6.87	2.26	1.36	6.67	2.07	1.33
14	Average	7.00	2.30	1.30	7.00	2.26	1.20

(4) = 44.102, the Kendall's coefficient of concordance is 0.525 and $p < 0.01$. Manufacturers targeting international market adopt quality management philosophies also to a moderate extent as shown by an average score of 2.48. A Friedman ANOVA test revealed X^2 (4) = 70.489, the Kendall's coefficient of concordance is 0.490 and $p < 0.01$. The study therefore concluded that manufacturers targeting international market adopt quality management philosophies slightly more than the manufacturers targeting domestic markets as shown in Table 4.16.

Table 4.16: Adoption of Quality Management Philosophies

Serial no.	Philosophy	Domestic market			International market		
		MR	M	SD	MR	M	SD
1	TQM program	3.52	2.81	1.03	3.86	3.00	1.07
2	ISO certification	3.62	2.81	1.03	3.58	2.83	.94
3	Quality activities	3.50	2.76	1.04	3.28	2.69	1.06
4	Statistical quality control	3.10	2.52	0.93	2.88	2.50	0.97
5	Six Sigma	1.26	1.43	0.51	1.40	1.42	0.50
6	Average	3.00	2.47	0.93	3.00	2.49	0.93

4.4.3.2 Understanding of the basic quality management principles

On manufacturers understanding of the basic quality management principles, the study found that manufacturers targeting domestic markets understand management principles to a large extent as shown by a mean score of 2.7. A Friedman ANOVA test indicates X^2 (11) = 16.059, the Kendall's coefficient of concordance is 0.070 and $p < 0.01$. Manufacturers' targeting international markets also understand basic quality management principles as indicated by a mean score of 2.54. A Friedman ANOVA test revealed X^2 (11) = 11.418, the Kendall's coefficient of concordance is 0.029 and $p < 0.01$. The study concludes that manufacturers targeting domestic markets understand basic quality management principles more than the manufacturers targeting international markets as shown in Table 4.17. Thus despite the perceived pressure by the international market, even the manufacturers targeting the local market strive to ensure quality in their products. This can be attributed to local pressure from the competition. Quality products save on the overall cost of production, while ensuring demand for products. These two factors, are a much greater motivator for quality incentives than the pressure from international markets.

4.4.3.3 Application of quality management tools

Both the manufacturers targeting domestic markets and the manufacturers targeting international markets applied management tools in their decision making to a moderate extent, and average of about 2.2 as shown in Table 4.18. A Friedman ANOVA test revealed X^2 (12) = 7.877, the Kendall's coefficient of concordance is 0.031 and $p < 0.01$ for manufacturers targeting domestic markets and a Friedman ANOVA test X^2 (12) = 9.994, the Kendall's coefficient of concordance is 0.023 and $p < 0.01$ for manufacturers targeting international markets. This can be attributed to the fact that even though the

Table 4.17: Understanding of the basic quality management principles

Serial no.	Principle	Domestic market			International market		
		MR	M	SD	MR	M	SD
1	Clear documentation	6.02	2.67	1.06	6.42	2.50	1.00
2	Need for continual change	7.52	2.90	0.89	6.03	2.50	0.91
3	Facility reliability	6.71	2.71	0.96	6.31	2.56	1.18
4	Commitment to CI	7.29	2.81	0.87	7.76	2.83	1.21
5	Workforce is flexibility	6.60	2.71	0.96	5.88	2.31	0.95
6	Commitment to training	7.31	2.90	0.89	6.71	2.61	0.84
7	Shortest throughput time	6.88	2.86	0.96	7.00	2.69	1.19
8	Reduction of costs	7.10	2.86	1.20	6.78	2.67	1.29
9	Lead times are measurable	6.69	2.71	1.06	6.01	2.44	1.16
10	Waste / misuse removed	5.40	2.43	1.33	6.57	2.56	1.03
11	Shop floor ideas	5.17	2.43	1.16	5.79	2.39	1.178
12	Satisfactory inventory	5.31	2.43	1.12	6.75	2.53	1.08
13	Average	6.50	2.70	1.05	6.50	2.55	1.05

manufacturers for the international markets have more quality awareness, their manufacturing processes are also more technology intensive, requiring minimal use of traditional tools.

4.4.4 Comparative Hypothesis 4: Older manufacturing organization practice CI in their operations

4.4.4.1 Adoption of Quality Management Philosophies

Overall, younger organizations started between 1991 and 2008, showed greater levels of adoption of Quality Management Philosophies as shown Table 4.19. The least adopters are organizations which were started between 1971 and 1991 as shown by a mean of 2.42, compared to means of 2.54 and 2.53 for the the younger and older manufacturing organizations respectively. However, the adoption of Six Sigma across all the organizations is low, with most organizations reporting a Mean Rank of less than 1.72.

Table 4.18: Application of quality management tools

Serial no.	Tool	Domestic market			International market		
		MR	M	SD	MR	M	SD
1	Pareto diagram	6.60	2.10	1.30	6.72	2.22	1.59
2	Cause effect diagram	6.62	2.10	1.26	6.81	2.25	1.32
3	Brainstorming	7.74	2.52	1.36	7.25	2.33	1.24
4	Flow charts	7.29	2.33	1.32	7.24	2.31	1.19
5	Check sheets	6.71	2.24	1.14	6.96	2.19	1.24
6	Histogram	6.62	2.05	1.43	6.67	2.19	1.12
7	SPC control charts	6.81	2.14	1.39	6.89	2.31	1.09
8	Scatter diagram	6.88	2.14	1.68	6.90	2.31	1.31
9	Design of experiments	6.33	2.10	1.51	5.99	2.03	1.46
10	FMEA	6.38	2.10	1.37	7.51	2.42	1.16
11	Capability analysis	8.24	2.48	1.36	7.96	2.50	1.34
12	Mistake proofing	7.98	2.48	1.29	6.36	2.11	1.41
13	Box plot	6.81	2.14	1.49	7.75	2.42	1.34
14	Average						

Table 4.19: Adoption of Quality Management Philosophies

Serial no.	Philosophy	Before 1970			1971-1990			1991- 2008		
		MR	M	SD	MR	M	SD	MR	M	SD
1	TQM Program	3.06	2.67	0.50	3.56	2.78	1.10	3.84	3.06	0.93
2	ISO Certification	3.22	2.67	1.00	3.77	2.84	1.02	3.38	2.81	0.91
3	Quality activities	3.44	2.89	1.17	3.36	2.66	1.10	3.44	2.81	0.91
4	Statistical quality control	3.56	2.78	0.83	2.98	2.44	0.91	3.06	2.63	0.89
5	Six Sigma	1.72	1.67	0.71	1.33	1.38	0.49	1.28	1.38	0.50
6	Average		2.53	0.87		2.42	0.95		2.54	0.84

$*$ = The year denotes the time the company was established

From the above results, the younger organizations adopt Quality Management Philosophies more because at the time of formation, quality was recognized as a major source of competitive advantage. Thus at the time of their formation, there was an inherent need to adopt the best practices at the time. Whereas older organizations were formed at a time when quality was not a priority.

4.4.4.2 Understanding of the basic quality management principles

The understanding of the the basic quality management principles is greater in older manufacturing firms, as indicated by an average score of 2.62 as shown in Table 4.20. A Friedman ANOVA test X^2 (11) = 17.189, the Kendall's coefficient of concordance is 0.174 and $p < 0.01$.

Middle aged manufacturing understand the basic quality management principles to least as shown by an average score of 2.59. A Friedman ANOVA test generates X^2 (11) = 13.385, the Kendall's coefficient of concordance is 0.038 and $p < 0.01$.

Younger manufacturing firms appear to understand basic quality management principles most as shown by an average score of 2.68. A Friedman ANOVA test X^2 (11) = 17.282, the Kendall's coefficient of concordance is 0.098 and $p < 0.01$.

Despite the fact that the young industries appear to understand the basic quality management principles more, it is important to note that overall, the sampled organizations indicated a general awareness of quality management. Thus, all the three categories score above average, with the highest average score going to new companies and the least going to the middle aged companies.

4.4.4.3 Application of Quality Management Tools

On the application of quality management tools, older firms applied the quality management tools in their shop floor most as shown by an average score of 2.36 as shown in Table 4.21. A Friedman ANOVA test X^2 (12) = 26.431, the Kendall's coefficient of concordance is 0.245 and $p < 0.01$.

Middle aged firms apply quality management tools to a moderate extent as indicated

Table 4.20: Understanding of the basic quality management principles

Serial no.	Principle	Before 1970			1971-1990			1991-2008		
		MR	M	SD	MR	M	SD	MR	M	SD
1	Clear documentation	6.67	2.67	0.87	6.14	2.53	0.98	6.38	2.63	1.20
2	Need for continual change	6.67	2.67	1.00	7.92	2.91	0.82	5.72	2.56	1.09
3	Facility reliability	7.89	2.89	1.05	6.78	2.69	1.00	5.59	2.44	1.15
4	Commitment to CI	5.00	2.33	1.12	6.61	2.56	1.11	8.53	3.13	0.95
5	Workforce is flexibility	4.11	2.11	0.78	5.36	2.25	0.88	7.78	3.00	0.97
6	Commitment to training	4.33	2.11	0.78	6.80	2.69	0.93	7.09	2.88	0.81
7	Shortest throughput time	6.17	2.56	1.01	6.34	2.59	1.07	7.28	2.94	1.06
8	Reduction of costs	7.33	2.78	1.09	6.52	2.63	1.18	6.81	2.81	1.28
9	Lead times are measurable	7.83	2.89	1.27	6.92	2.75	1.11	6.19	2.50	1.10
10	Waste / misuse removed	7.50	2.89	0.60	6.27	2.53	1.16	5.22	2.38	1.09
11	Shop floor ideas	7.83	2.89	0.78	5.84	2.47	1.16	5.75	2.50	1.15
12	Satisfactory inventory	6.67	2.67	0.87	6.50	2.59	1.07	5.66	2.44	1.09
13	Average		2.62	0.95		2.60	1.05		2.68	1.09

by an average score of 2.25. A Friedman ANOVA test X^2 (12) = 10.633, the Kendall's coefficient of concordance is 0.497 and $p < 0.01$.

Younger firms apply quality management tools least as shown by a mean average score of 2.17. A Friedman ANOVA test X^2 (12) = 5.574, the Kendall's coefficient of concordance is 0.029 and $p < 0.01$.

From these findings, older firms apply quality management tools most followed by middle aged manufacturing firms. The uptake of the quality management tools in the shop floor is however below average for the three categories. This concurs with the general uptake of quality management tools where the respondents indicated that it was generally below average. In general, it appears that although the most manufacturing firms in Kenya are aware of the quality management practices and philosophies, they are not taking the practice to the shop floor. Thus there is a low usage of tools that can be used to improve the quality of the products. This can be attributed to a general lack of awareness on the tools available, or on the proper method of using them.

Table 4.21: Application of Quality Management Tools

Serial no.	Tool	Before 1970			1971-1990			1991-2008		
		MR	M	SD	MR	M	SD	MR	M	SD
1	Pareto diagram	4.06	1.67	0.50	6.81	2.22	1.31	6.28	1.94	1.65
2	Cause and effect diagram	5.22	2.11	0.93	6.33	2.13	1.10	7.06	2.13	1.45
3	Brainstorming	7.44	2.56	1.13	7.11	2.31	1.18	7.41	2.44	1.31
4	Flow charts	9.50	3.00	1.00	7.64	2.44	1.13	6.06	2.00	1.32
5	Check sheets	9.28	2.89	0.93	6.89	2.22	1.01	7.34	2.31	1.40
6	Histogram	7.44	2.33	1.00	7.31	2.31	1.06	6.94	2.13	1.59
7	SPC control charts	9.06	2.78	1.09	7.86	2.50	1.19	6.41	2.06	1.29
8	Scatter diagram	6.94	2.33	1.00	7.11	2.25	1.24	7.44	2.31	1.74
9	Design of experiments	8.22	2.67	1.32	6.05	2.00	1.46	6.72	2.13	1.50
10	FMEA	5.56	2.00	1.00	6.72	2.19	1.35	7.16	2.19	1.28
11	Capability analysis	5.00	1.89	1.17	7.89	2.44	1.41	7.47	2.25	1.34
12	Mistake proofing	6.78	2.33	0.87	7.06	2.31	1.26	6.47	2.00	1.41
13	Box plot	6.50	2.22	1.39	6.22	2.03	1.40	8.25	2.44	1.36
14	Average		2.37	1.05		2.26	1.18		2.18	1.44

CHAPTER FIVE

5.0 MODEL VALIDATION

One of the objectives of the research was to validate the computer based model that was developed. This was done by applying it in two small scale manufacturing organizations. Company A specialized in manufacturing filters for automobiles and prime movers. Company B was a small scale dairy firm. In this chapter, we describe the methodology and the results from the two cases.

5.1 Company A: Filter Making Company

5.1.1 Company Background

The company manufactures over 100 different types of filters, and employs around forty employees. The filters are used in the automobile industry, generators and earth moving machinery. The filters can be categorized by use, shape, size or end sealing mechanism. By use they can be categorized as air, oil or fuel filters. By shape they can be classified as panel filters, round filters or conical filters. By size they can be classified by the size of their pleats, and physical size of actual filter. By sealing they can be categorized as metal capped or polyurethrene sealant capped. Typically the company manufactures around 1000 filters in one day. Some of their products are shown in Figure 5.1.

5.1.2 Quality Management Practices

The company strives to ensure that they meet all their customers' requirements, both internal and external customers. There are no formal Quality Management measures and the tools that they use are more of a common sense approach to quality. For example each operator is charged with the responsibility of ensuring that he does not transmit a faulty part to the next stage of production. In addition, the operator is supposed to find the cause of the problem if the defects become "too many". The metrics of the "many"

Figure 5.1: Assortment of some final products

defects are not clearly defined. What is acceptable is mainly by the feel of the respective operators. Thus,while the external customer may not get any defective products, a lot of defective products will be produced and disposed as waste within the system.

The manufacturing process is not documented. Lack of process data means that it takes time before a special cause of variation is detected. It also means that the causes of variation are not traceable to the source easily. The success of the operations can be directly attributed to the operators' knowledge.

The production manager is well trained on ISO certification and other quality related tasks. Other employees have not undergone any formal training on quality management.

5.1.3 Methodology

The methodology describes the quality project tackled outlining the various steps that were followed, and the inputs that were input into the computer code and explaining rationale behind the inputs. The tools recommended by the computer code are also highlighted.

5.1.3.1 The Quality Project

The main quality concern at the time of the study was that there were inconsistencies on the panel filters end sealing. The panel filter's elements ends are glued together by hot melt. Inconsistent hot melt leads to a defective filter since it will leak in the ends. The Figure 5.2 shows a defective panel filter element, while Figure 5.3 shows a defect-free element. In addition when too much hot melt gets to the pleated paper it leaks on the edges, the filter will not fit and generally lacks aesthetic appeal.

A quality improvement Team was formed. The quality improvement team consisted of the production manager and the three machinery operators. The production manager was aware of the principles of quality management, from prior training. The staff members were all "quality conscious" in that no one would take a defective product to the next stage of production, but had no formal or on-job quality training before. It was explained to the Team that the role of the computer program would be to offer guidance on the selection of the quality management tools to be used in the project. Minitab R15, Minitab Quality Companion and MS VISIO quality management tools suite were also introduced. These were presented as the computer-based aids to quality.

The computer program was used for tool selection. The Team input information to the program depending on their needs. The program would then recommend a tool. The actual tools used were generated from a Minitab R15, Minitab Quality Companion 2, and MS VISIO.

The program was run for the first time after the problem had been identified. In this

Figure 5.2: A defective panel filter element

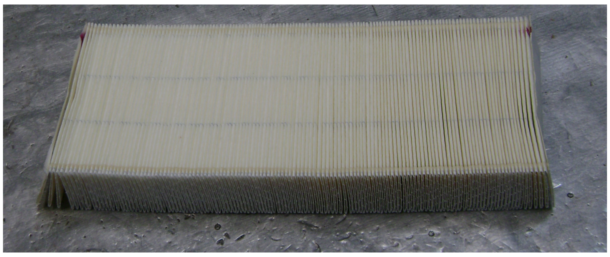

Figure 5.3: A defect-free panel filter element

project, it was decided to use the Six Sigma methodology, DMAIC, since the steps in Six Sigma are more definite and are thus easier to use in a manufacturing situation as opposed to the Demming Cycle that is easier to use in a managerial situation. Each phase was explored until the objectives of each phase were met.

5.1.3.2 Summary of input parameters against selected tools

The parameters input to the code versus the outputs of the code are shown in the Table 5.1 below. The tools selected by the code were used in the quality improvement project

5.1.4 Results and Discussions

The results of running the program are described for each of the project phases. Each phase is analyzed and discussed. For each of the five steps outlined in the methodology above (Define, Measure, Analyze, Improve, Control), the results of using the recommended tool are discussed. A summary of the tool effectiveness as rated by the quality

Table 5.1: A Table of the input parameters against output tools

Run	Phase	Tool type	Works with	Outcome	Classification	Capabilities	Output
1	Define	A	I	Diagram	Tool	Organize/Prioritize	Flowchart
2	Define	A	I	Matrix	Tool	Organize/Classify	Brainstorm
3	Define	A	I	Diagram	Tool	Organize/Prioritize	Cause & Effect
4	Measure	A	N	Matrix	Tool	Organize/Count	Check sheet
5	Analyze	S	N	Chart	Tool	Status/Predict	Control chart
6	Improve	S	N	Matrix	Technique	Compare/Generate	Design of Experiments
7	Control	S	N	Chart	Tool	Status/Predict/compare	Control charts

improvement Team is also included.

5.1.4.1 Define

The objectives were to define and scope the project. The defect was also defined and documentation of the project started. The objective of the project was to reduce the number of defective panel filters' elements. The defect was defined as any panel element whose end sealing had a skipped portion, on either of the two sides. The obvious cause of defect was inconsistencies in the pouring of the hot melt from the nozzles. The nozzles skipped portions of the panel filters randomly, and for various lengths. Several factors could have made the nozzle skip the portions. It was decided the length of the skip was immaterial as any skipped panel was not usable. The information on the average number of defects was not available and therefore the general objective was thus to reduce the defects and not to a particular percentage at this time. The program was run and flowchart was selected as the first tool. The Team was able to easily come up with a flow chart using MS VISIO shown in Figure 5.4. The flowchart was discussed by the team and a smaller panel filter flowchart extracted from the main flowchart shown in Figure5.5. A schematic flowchart of the end sealing process was developed as shown

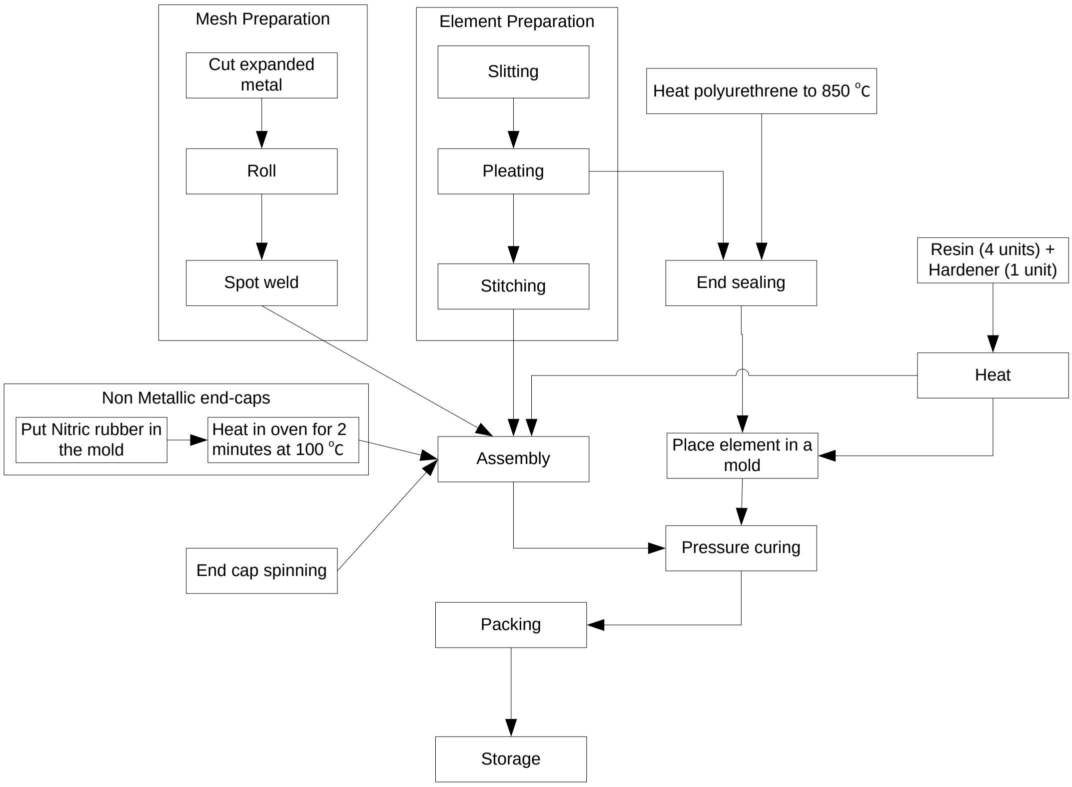

Figure 5.4: A flowchart of the filter-making process

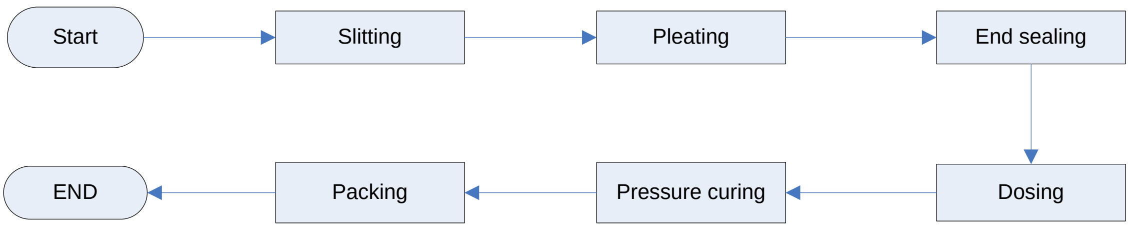

Figure 5.5: Extract of the flowchart showing the filter-making process for a panel filter

in Figure 5.6. Both the schematic and the flowchart (developed using MS VISIO) were studied by the Team. The Team needed a tool that could assist in generation of ideas on what the probable causes of the inconsistency were. The parameters in run 2 were input and the tool selected was brainstorming. The possible causes of the defects were listed on Minitab's brainstorm list. To organize the ideas, the program was ran with

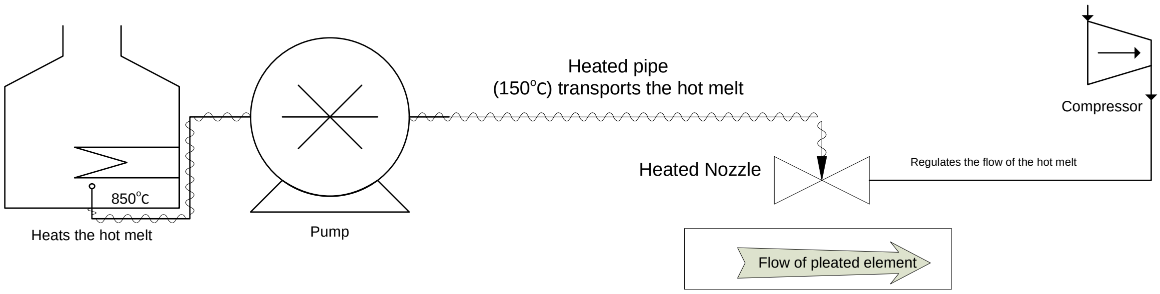

Figure 5.6: A schematic flowchart of the end-sealing process

the parameters on run 3 and Cause and Effect diagram was the recommended tool. The ideas were arranged on Minitab's Quality companion Cause and Effect Diagram and the resulting diagram is shown in figure 5.7.

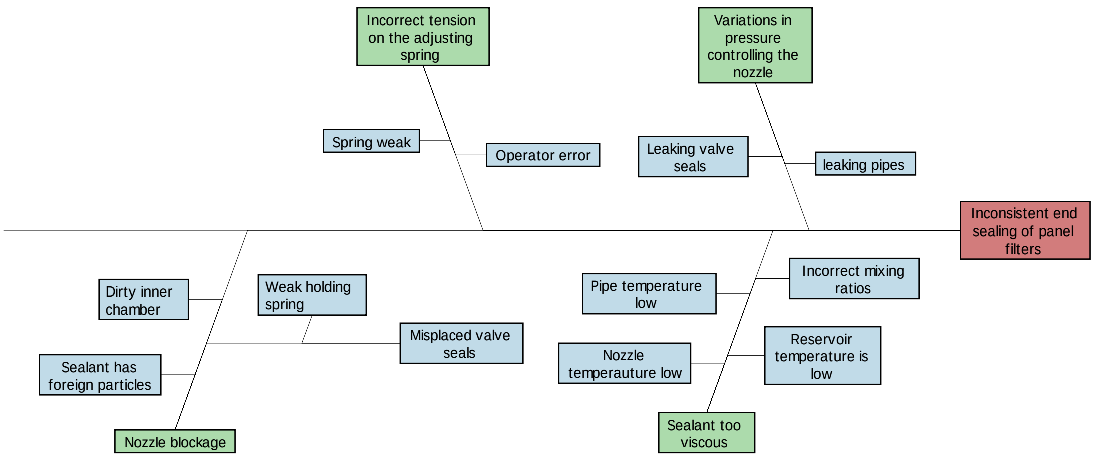

Figure 5.7: Cause and Effect diagram of the causes of inconsistent end-sealing

5.1.4.2 Measure

The objective of this phase is to determine metrically the defects the process produces. The program was run with the parameters on run 4 and control charts were selected as the appropriate tool. The program indicated checksheets as a prerequisite to use control charts. A sample check sheet with data is shown in figure 5.8, and was picked from Minitab's forms. Since there was no prior data on the process performance, data was collected.

DATA SHEET FOR np CHART

Company............*Pantech Kenya ltd*.......................

Department.........*Production*............................ Part description......*Panel filter*...............

Date	*Time*	*Inspected by*	*Number inspected*	*No. of defectives*	*Fraction defective*	*Comments*
25/3	12.30 PM	Kithinji	50	4		
25/3	4.30 PM	Kithinji	50	4		
26/3	10.30 AM	Maina	50	6		
26/3	12.30 PM	Kithinji	50	5		
26/3	4.30 PM	Kithinji	50	2		
27/3	10.30 AM	Kithinji	50	0		
27/3	12.30 PM	Kithinji	50	6		
27/3	4.30 PM	Maina	50	1		
28/3	10.30 AM	Kithinji	50	2		

Figure 5.8: Check sheet for data collection

The type of control chart used was attribute control charts since the data was categorized as either defective or defect free. An nP control chart was used. In order to determine whether process was stable or had special causes of variation, data for 25 samples was collected. The sample size was 50 and data was collected three times a day. The data was fed into Minitab R 15 program for analysis.

5.1.4.3 Analyze

The objectives of this phase is to check for causes of defects, and check whether the process is stable or has special causes of variation. The program was run with parameters in run 5 and control charts were selected. Data was tested using the universal tests for special variation. A process exhibits a special variation if:

1. any point falls outside of the control limits;

2. any two out of three consecutive points fall more than two standard deviations from the centerline, on the same side of the centerline;

3. four out of five consecutive points fall more than two standard deviations from the centerline, on the same side of the centerline;

4. eight or more consecutive points lie on the same side of the centerline;

5. eight or more consecutive points move upward or downward in value;

6. thirteen or more points fall within one standard deviation on either side of the centerline.

A special cause of variation was identified for data point 19, as shown in Figure5.9 In

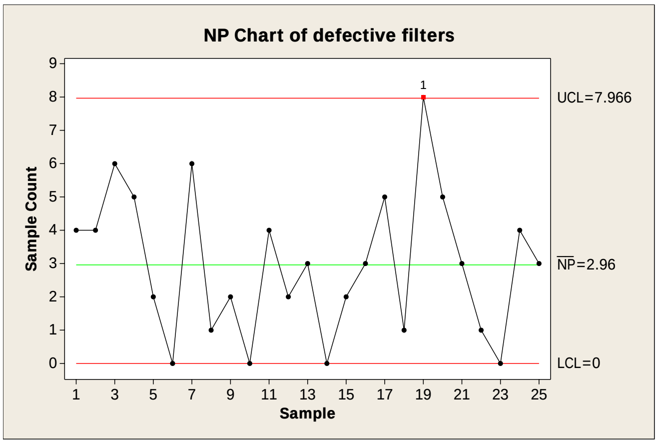

Figure 5.9: The control chart for the process

order to improve the process, the causes of special variation had to be removed. On further informal investigation, it was discovered that the operator who fed hot melt material to the tank that morning had recently been hired and had not been well inducted. He had not let the melt to heat long enough before starting to use it. To prevent this from re-occuring, clear instruction explaining hot melt tank temperature and durations were made and posted next to the machine. The control limits were recalculated without the out of control point and the process was found to be stable with a percentage error of 5.5 percent as shown in Figure5.10. It was decided that there was need to reduce

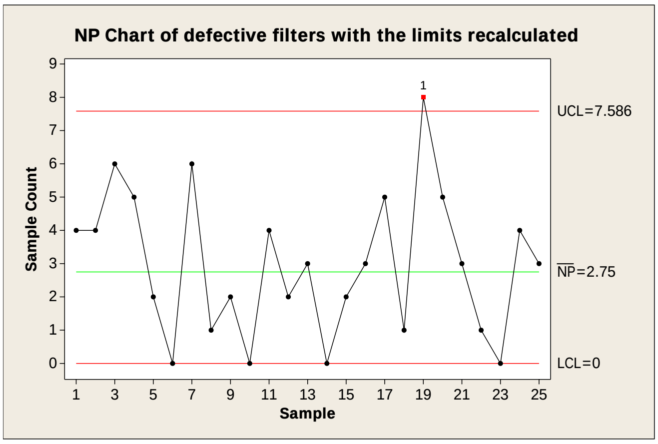

Figure 5.10: The control chart with recalculated limits

the percentage. Both the flow chart and the cause and effects diagram were printed for further analysis. It was observed that the root cause of the problem appeared to be the nozzle. The nozzle was dismantled and studied. A diagram of the nozzle is shown in Figure 5.11.

5.1.4.4 Improve

In this phase the program was run with parameters in run 6. Design of Experiments was recommended. From the above analysis in the analyse phase, three likely solutions emerged;

- Raise the temperature of hot melt to reduce viscosity,
- Change the mode of regulating the nozzle from the pneumatic to mechanical (by use of a screw)

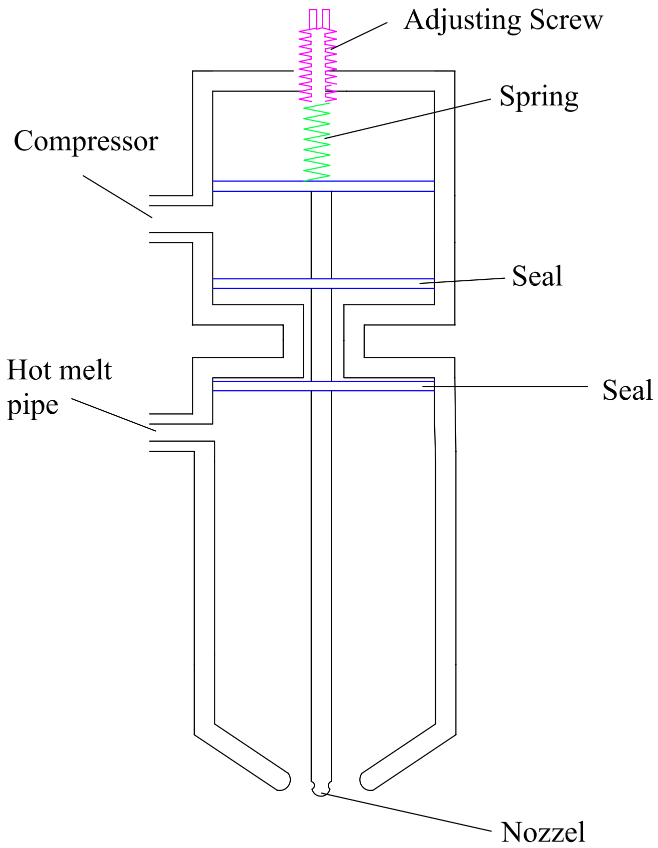

Figure 5.11: A diagram of the end-sealing nozzle

- Insert a spring in the nozzle to hold the seal in place to prevent blockage

The experiment was designed to be a one factor at a time experiment. The tank temperature was raised by 50 degrees, pipe 30 degrees, and nozzle by 20 degrees celcius. Then data for the process was collected using a check sheet. In order to determine the means for presentation and analysis of the information, the program was run with parameters in run 7. The tool recommended was Control charts. From the chart, it could be seen the process had deteriorated with percentage error increasing to 23.2 percent, as shown in Figure5.12. This was because the change had introduces a new defect completely absent initially; the decreased viscosity meant that the hot melt was passing through the elements pores, and burning the element. This was discontinued. Using one of the valves

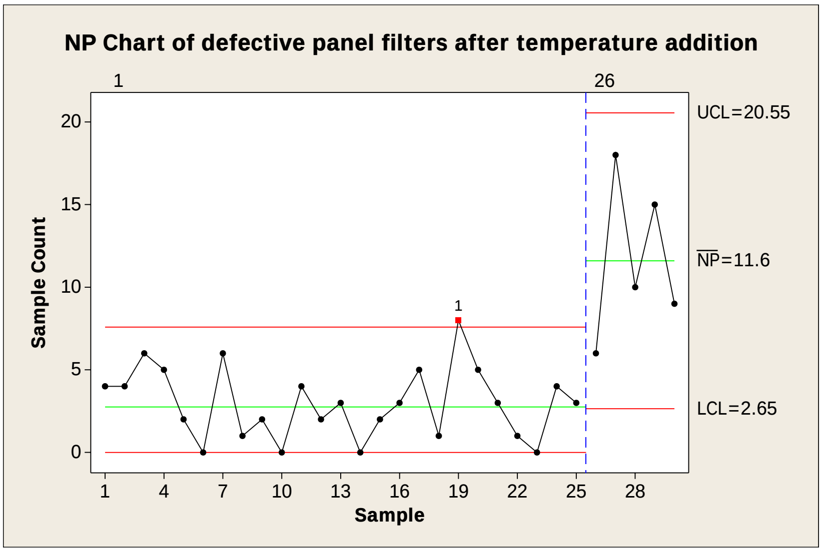

Figure 5.12: The control chart with temperature adjusted

as a control, the pneumatic portion was shut off and the push rod welded to the adjusting screw as shown in Figure 5.14, so that the flow was regulated directly by turning the screw. Data was collected for 5 samples of 50 and analyzed. The resulting control chart is shown in Figure5.13. The process produced an average of 1.82 % defects. Since the

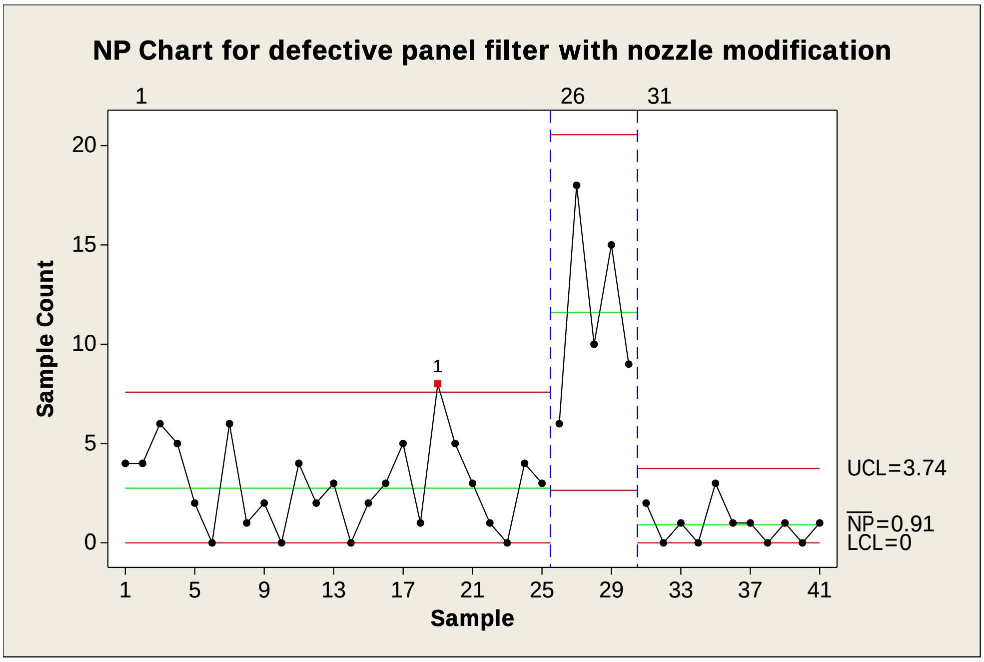

Figure 5.13: The control chart for the entire quality improvement exercise (temperature adjusted and modified nozzle)

modification was done for one nozzle, it was anticipated that changing the other nozzle would reduce the process error to less than 1 %. The fluctuations were thus attributed to the pneumatic system and the solution was to convert both nozzles to a mechanical system once further studies had been made, to ascertain the long term stability of the modified nozzle.

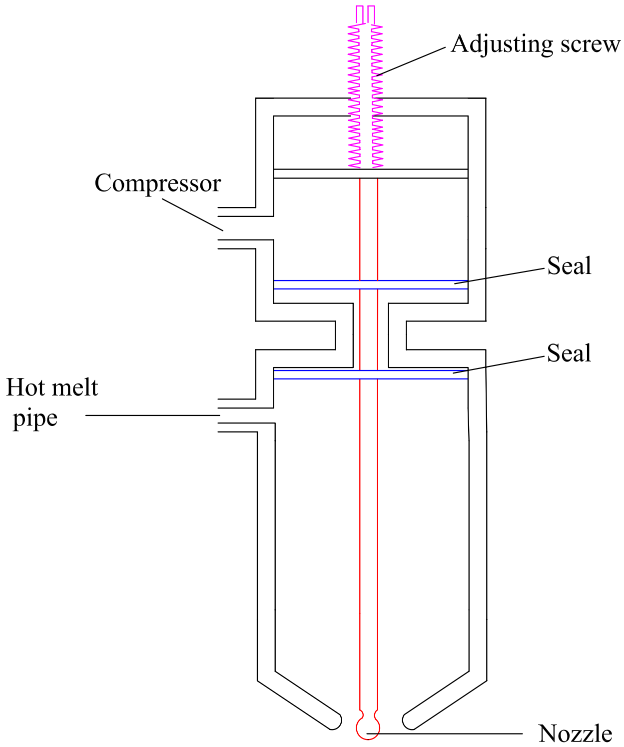

Figure 5.14: Modified design of the the end-sealing nozzle

5.1.4.5 Control

The control part of the quality improvement effort involved the adoption of the new nozzle design, and a commitment to monitor the performance of the end sealing machine. In addition, the instructions posted on the end-sealing machine prevented a repeat of a special variation error.

5.1.4.6 Summary of tools effectiveness

The tools recommended were rated for effectiveness (High, Medium, or Low) by the team after the completion of the project. The reasons for the rating were given and were recorded in the last column of the Table 5.2.

Table 5.2: A Table of the effectiveness rating of the used tools

	Tool	Phase	Effectiveness	Explanation
1	Flowchart	Define/Analyze	High	Effective for understanding the process the steps involved. It gave a "picture" of the process
2	Brainstorm	Define	High	Effective in generating improvement ideas. The semi-informal setting enhanced creative problem-solving
3	Cause and Effect Diagram	Define	High	A very effective tool for sorting out ideas and understanding the inter-relationship
4	Check sheet	Measure	High	Simple but effective data collection tool
5	Control charts	Analyze/Control	High	Provides a visual display of the process performance. Indicates trends not noticeable by simple data collection
6	Design of Experiments	Improve	Medium	A complex tool to use but the simplicity of the process made it useable. The experiment design was one factor at a time, which is the lowest level posible

In general, the tool was able to reduce the process percentage error from 5.5 % shown in Figure5.10 to 1.82 % shown in Figure5.13, a reduction of approximately 3 %. The percentage is obtained by multiplying the error count number by two since the sample size is 50. For a company that manufactures typically 1000 filters in a day, a three percent reduction signifies a reduction from 50 defective filters per day to 20 defective filters representing a huge saving.

5.2 Company B: Dairy Processing Factory

5.2.1 Company Background

The main products for the dairy are short life milk (half litre and a quarter litre packets), long life milk (UHT), raw un-processed milk, yoghurt, butter and ghee. The dairy also sells semi-processed milk to other re-sellers and institutional customers and hoteliers. The dairy has an installed capacity of 50,000 litres of milk per day, but on average processes around 20,000 litres per day. The difference is brought about by milk shortage. This has been as a result of intense competition from other milk processors who are buying the milk from the farmers in the area at a better price.

5.2.2 Milk Processing

Below is brief description of the process from raw milk to processed and packaged milk.

5.2.2.1 Reception

Milk is brought from the farm to the dairy for processing. When received at the dairy, the quality of the milk is checked. The tests carried out are discussed in the next section.

The milk, is cooled to - 4 ^{o}C, and taken through a separator for cream separation. The cream is used for the manufacture of butter. The milk is then transported to the storage tanks where it is stored awaiting further processing. Some of the milk in the storage tanks is re-sold unprocessed and unpacked to be used in the local hotels or other institutional customers. The rest is homogenized and pasteurized.

5.2.2.2 Homogenizing and Pasteurization

Homogenising and Pasteurization Homogenization breaks up the fat globules in the milk by forcing them through a fine aperture, allowing the remaining cream to be mixed evenly throughout the milk. Homogenisation diminishes the tendency of the fat globules to clump together and coalesce into cream.

After homogenization the milk is pasteurized. Pasteurisation is a heat treatment that destroys unwanted or disease-causing bacteria without reducing the nutritional quality of milk. Pasteurisation ensures milk quality and a longer shelf life. Depending on the final product required, different pasteurization temperatures and durations are used. For short life milk (3 days), the milk is heated to between 72 ^{o}C and 75 ^{o}C and held in that temperature for 15 seconds. For long life milk (UHT), the milk is heated to between 135 ^{o}C and 140 ^{o}C and held in that temperature for 4 seconds.

5.2.2.3 Packaging

1. **Short life milk packaging**

   The short life pasteurized milk is packed in plastic sachets. There are five similar machines that are used in packing of the short life milk. The sachets are produced continuously from a roll of polyethylene paper and are sterilized using Ultra Violet light before being filled and sealed. The transverse seals are generally made above milk level. The packages are separated by guillotine and placed in rectangular plastic crates holding 20 packages each and the crates are then palletized. The same width and thickness is used for both $\frac{1}{2}$ - litre and $\frac{1}{4}$ - litre packages; capacity is varied by varying the distance between transverse seals. It is important that the film is free from pinholes or micro pores.

2. **Long life (UHT) Packaging**

   The long life milk is packed in rectangular cartons made from polyethylene laminated paper board. There is one UHT packing machine. The cartons are produced continuously from a roll of plastic-coated paper which is chemically and thermally sterilized before being shaped and sealed into a tube. The tube is filled continuously with UHT processed milk, after which the cartons are sealed below fluid level and formed into a rectangular shape. The cartons are filled completely and can be stacked.

5.2.3 Quality Management Practices

The dairy has a department of quality control. The department is charged with the responsibility of ensuring that the milk meets the quality requirements and that the milk processing meets the set quality standards. Taste and smell are used as preliminary indicators of milk quality, and visual observation is also used. If the person receiving the milk suspects that it is of poor quality, he or she carries out one of the following tests:

1. organoleptic

   This encompasses a visual inspection of the milk to check whether any particles can be detected visually, and that the colour of the milk is white. Taste and smell of the milk are also inspected at this stage.

2. lactometer

   Tests for presence of added water

3. PH

   Tests whether the milk is mastitic or sour

4. Resazulin

   Tests for the proteins present in the milk

5. Butterfat

   Tests the butterfat content of the milk

Once the quality of the milk is ascertained, the milk is accepted for processing. The quality department is allowed to reject milk that does not meet the required standards. In such cases the department communicates the reason for rejection to the supplier.

During processing, the department monitors the various temperatures to ensure that at all times, the milk in the storage tanks, and in the production line is within the required temperatures. If there is a discrepancy between the actual and the expected, the quality control department notifies the production department. Once the milk is processed, the department picks hourly data on the processed milk. Each hour, three packets from each of the five packing machines is picked, weighed, inspected and stored for incubation to carry out further tests.

The number of leaking packets for each machine is not recorded. For these packets, a PH test is done after one day, two days, and three days. This is supposed to give an indication as to the performance of the milk in the market. The department keeps track of the data by entering it in a table. No graphical analysis was used. There are no aids to data analysis such as charts or computerized analysis. The presence of a problem is indicated by presence of a deviant data point. This approach misses a critical aspect of quality management; trends. Without charts there is no way of identifying trends and thus there is no way of predicting future performance.

5.2.4 Methodology

5.2.4.1 Identification of the quality concerns

The study focused on the short life packing machines. The area was chosen because of its frequent break downs. The main nonconformity observed was leaking milk satchets. Presence of leaks, visible or invisible was a main problem as it reduced the shelf life of the milk. There were five identical machines. The machines were fully automatic but required constant presence of attendants to monitor their production. The variables that were adjustable include the sealing temperature, the volume of the milk, and guillotine pressure. If a leakage was detected, the machine was stopped and the causes for the leaks investigated. The leaking packages were cut and the milk reprocessed again, The area around the packing machines had lots of milk on the floor and required presence of running water at all times.

Since the organizational structure is such that the quality control and the production departments are different departments, it was not possible to form a quality improvement team. This posed problems because for the tools that required teamwork, the researcher had to solicit information from each person involved in the machine individually. However, there was no problem with collecting process data. All the data needed was readily accessible. Data was collected on two main locations; the packaging machines and the laboratory results. The data collection was simultaneous.

The computer program was used for tool selection. The researcher input information to the program depending on his needs. The program would then recommend a tool. The actual tools used were generated from a Minitab R15, Minitab Quality Companion 2, and MS VISIO.

5.2.4.2 Summary of input parameters against tools used in the project

The parameters input to the code versus the outputs of the code are shown in the Table 5.3 below. The tools selected by the code were used in the quality improvement project.

Run	Phase	Tool type	Works with	Outcome	Classification	Capabilities	Output
1	Define	Analytical	Ideas	Diagram	Tool	Prioritize, groups	**Flowchart**
2	Measure	Analytical	Numbers	Diagram	Tool	Provide status	**Control chart**
3	Analyze	Analytical	Ideas	Diagram	Tool	Organize/classify	**Cause & Effect Diagram**
4	Analyze	Statistical	Numbers	Diagram	Tool	Predict	**Control chart**
5	Improve	Statistical	Numbers	Matrix	Technique	Compare	**DOE**

Table 5.3: A Table of the input parameters against recommended tools

5.2.5 Results and Discussion

The results of running the program are described for each of the project phases. Each phase is analyzed and discussed.

5.2.5.1 Define

The defect was defined as any leaking package. The objective of the quality initiative was to reduce the number of defective packages. From the reference code, the recommended tool was a flowchart. With the assistance of the people working with the packing machine, a simplified flowchart of the system was developed. The flowchart of the entire process is shown in Figure5.15 while an extracted flowchart of the packing process is shown in Figure5.16

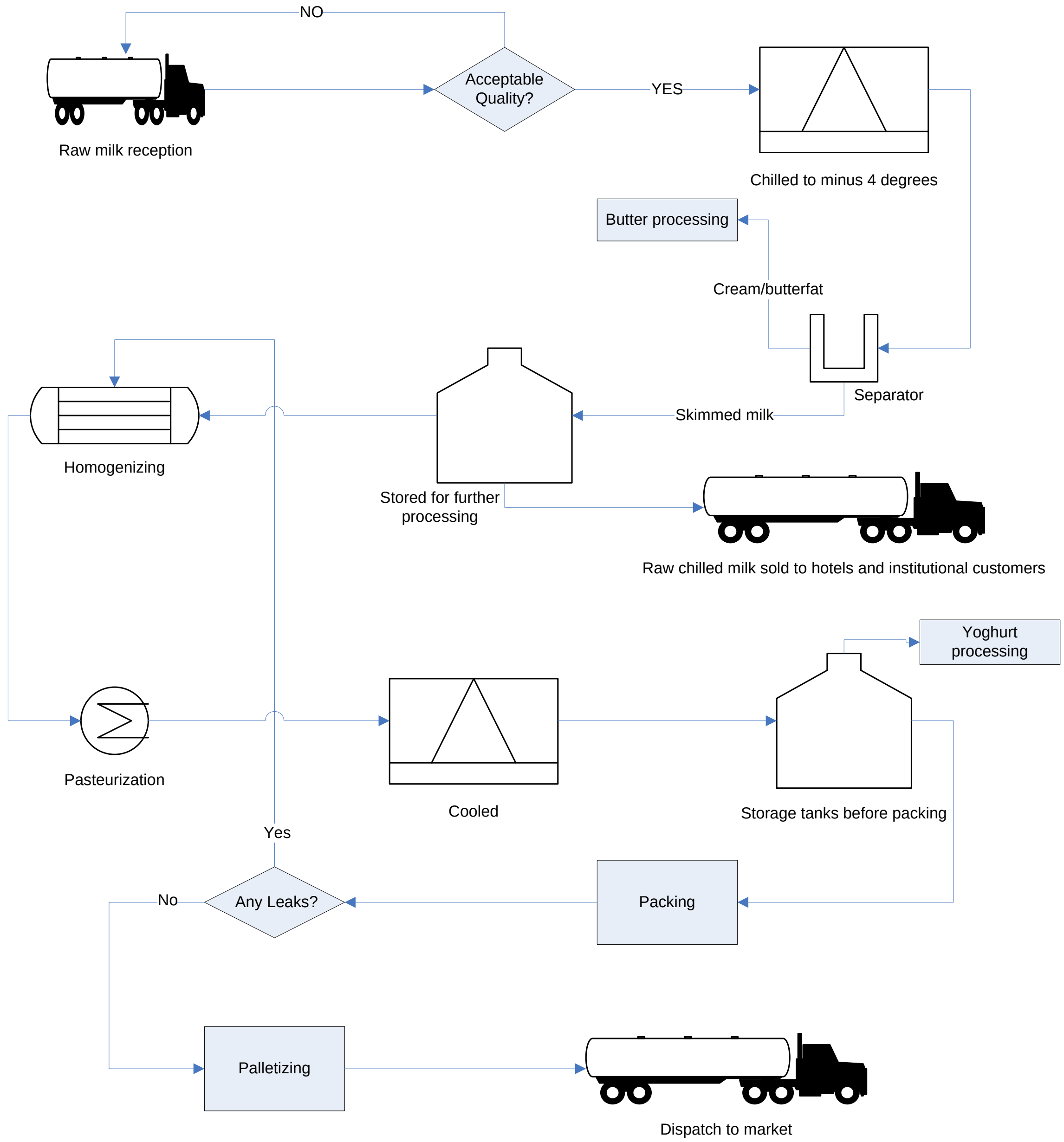

Figure 5.15: A flowchart of the milk processing plant

5.2.5.2 Measure

In order to improve a process, the present performance is needed. From the reference code, the correct tool was the control chart. This required the use of check sheets as a pre-requisite. Thus a check sheet was developed. The performance of the packing machines could also be determined from the laboratory data. This required initial data collection

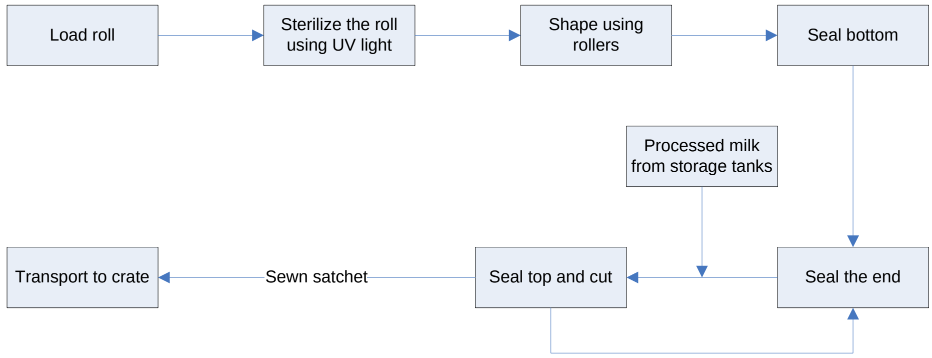

Figure 5.16: A Flowchart of the short-life (satchet) packing process

to determine the present level of defects. Since outputs of five packing machines was 4500 packets per hour, a sample size of 250 packets per hour, distributed evenly among the five packing machines was selected. After four days, there was adequate data to determine the overall process performance. Control charts were constructed for each of the machines and the overall process. The type of charts constructed was a NP control chart. The charts are shown in Figures5.17, 5.18, 5.19, 5.20, 5.21 and 5.22 It was found

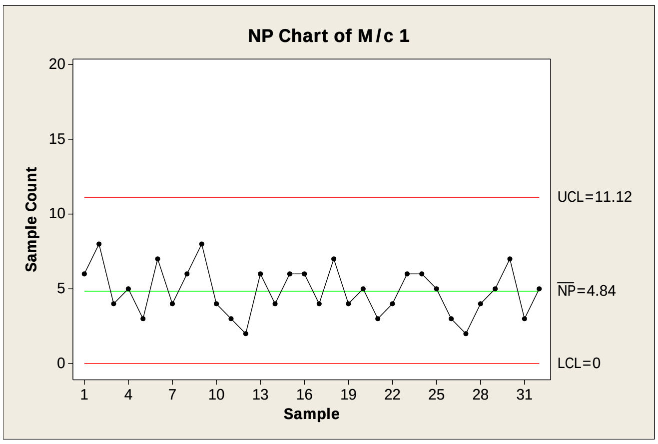

Figure 5.17: A control chart of packing machine 1

that machine 1, 2, 3 and 5 were stable with process mean of 9.7 percent, 6.6 percent, 6.4 percent and 9.2 percent respectively. Machine 4 was unstable and had a process mean of 16.8 percent. The overall process was stable with a defect rate of 9.2 percent.

Simultaneously, data was collected in the laboratory on the PH tests. This was collected

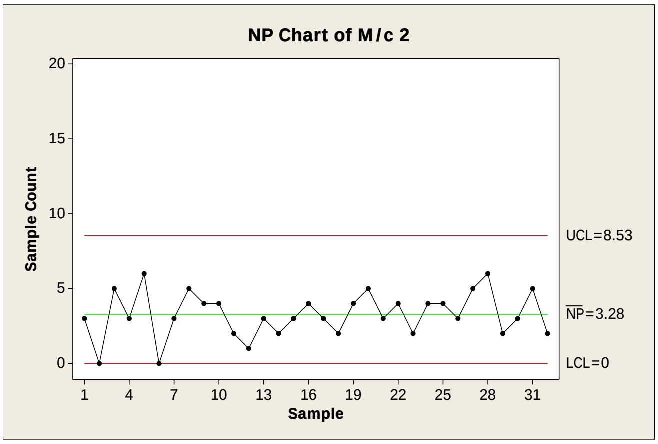

Figure 5.18: A control chart of packing machine 2

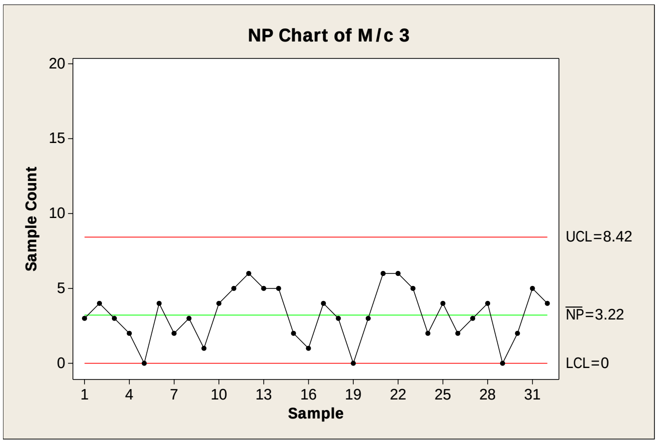

Figure 5.19: A control chart of packing machine 3

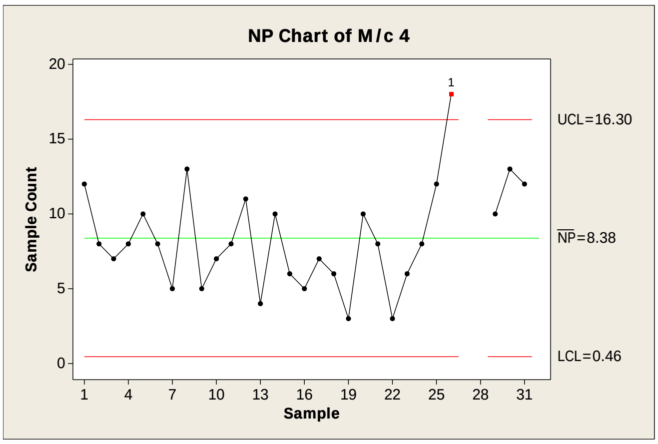

Figure 5.20: A control chart of packing machine 4 with discontinuities where machine was stopped for repair

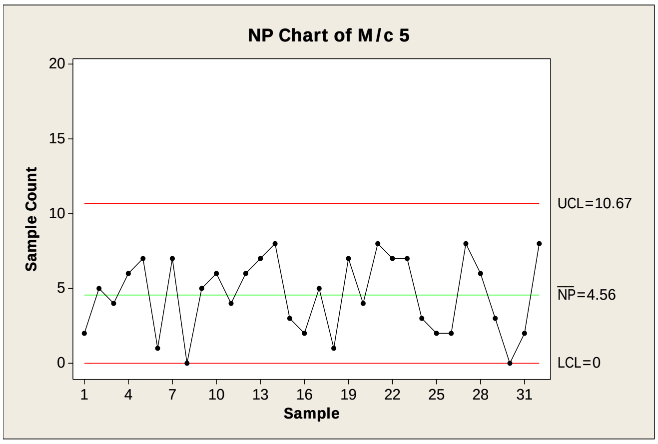

Figure 5.21: A control chart of packing machine 5

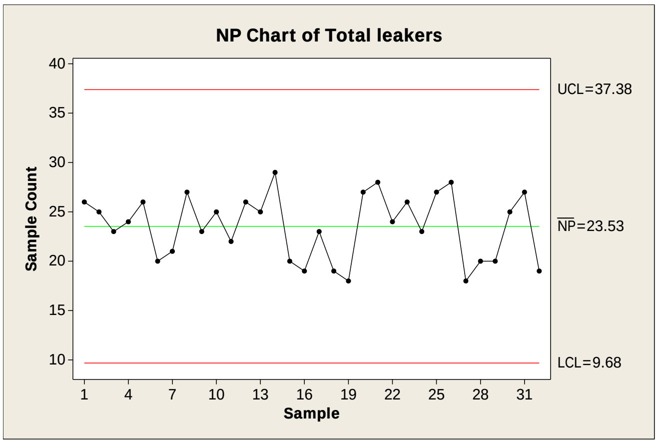

Figure 5.22: A control chart for the packing process (five packing machines combined)

from the hourly samples taken by the Quality Control department. Each hour, three packets from each machine were taken and incubated in the lab at 32 degrees Celsius. The PH of one packet was tested after 24 hours, the other after 48 hours and the other after 72 hours. Using this data, attribute control chart were constructed. The charts were drawn for the three time periods separately. Since the data used was continuous in nature, variable control charts were used. The limits for the charts were set at a PH level between 6.50 and 6.80 with a mean of 6.65. These values are standard for milk processing. The charts are indicated in figures5.23, 5.24, 5.25, 5.26, 5.27 and 5.28. The charts for machines 1, 2, 3 and 5 indicated stability while data for machine 4 indicated a gradual increase in milk acidity for day (24 hrs) old milk. These correlates the findings of the charts constructed from packing machines.

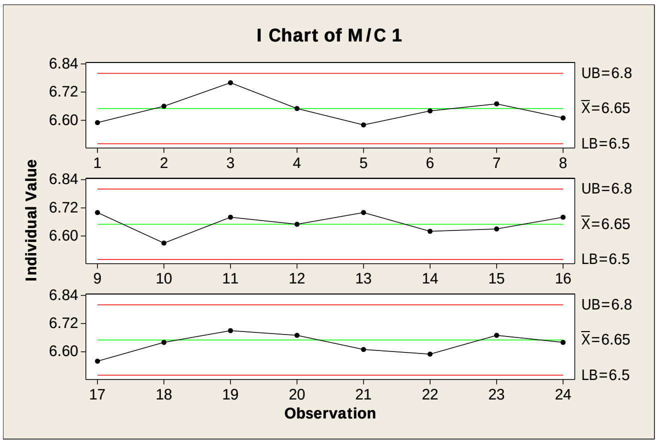

Figure 5.23: A 3 - day PH control chart of packing machine 1 (24 hr incubation)

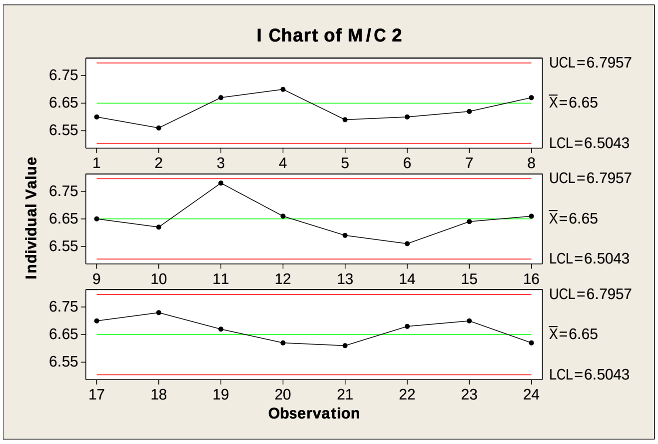

Figure 5.24: A 3 - day PH control chart of packing machine 2 (24 hr incubation)

5.2.5.3 Analyze

The recommended tools were control charts and Cause and Effect diagrams. The charts indicated that machine 4 had a problem. Even before the out of control point on data point 26, the machines lab results for the milk that was one day old indicated a lowering trend in PH level. Thus even though acidity was within the specified limits, there were

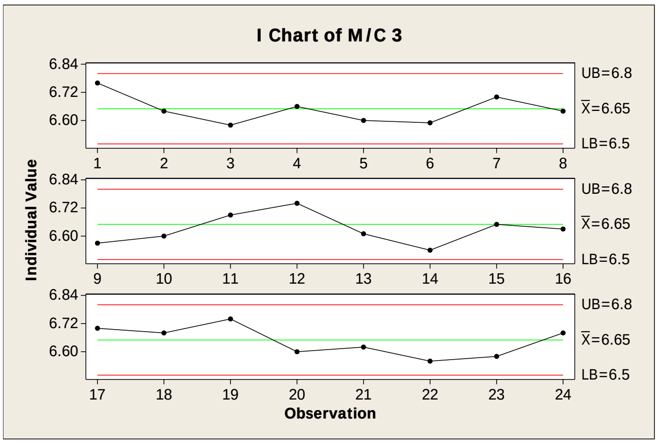

Figure 5.25: A 3 - day PH control chart of packing machine 3 (24 hr incubation)

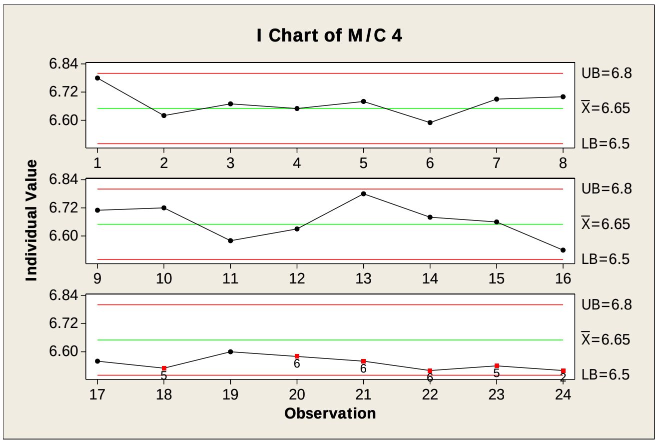

Figure 5.26: A 3 - day PH control chart of packing machine 4 (24 hr incubation) with six out of control points

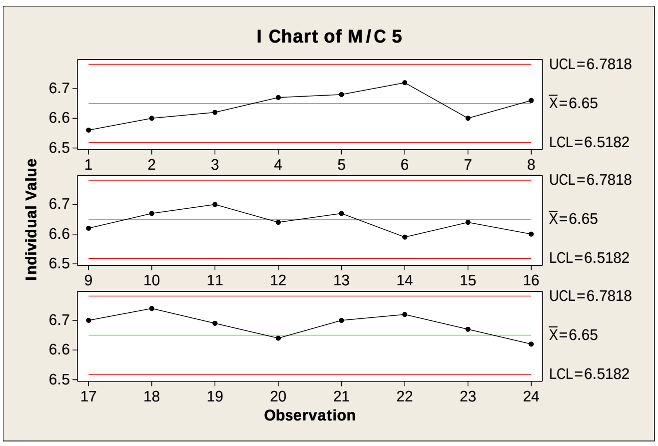

Figure 5.27: A 3 - day PH control chart of packing machine 5(24 hr incubation)

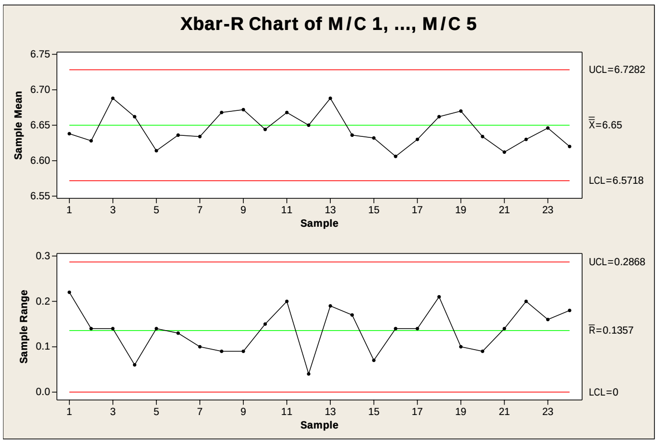

Figure 5.28: A 3 - day (24 hr incubation) PH control chart for the packing process (five packing machines combined)

indications that there was trend towards an increase in acidity. This suggests the presence of pinholes and micro-pores before the main leaks. The implication is that since the milk at this time is still within the acceptable limits (from lab results), the data can be used to predict 'leakers', and corrective action can be taken before the actual leaking starts. The next step would be to determine the probable causes of leaking. The causes identified were as shown in the Cause and Effect Diagram in Figure5.29. These causes were gotten from the operators of the machine. The causes were not exhaustively discussed because the operators either did not know or were unwilling to reveal what they knew. This showed prevalence of a quality culture based on inspection.

5.2.5.4 Improve

The recommended tool was Design of Experiments. The prevalent culture prevented the testing of the various parameters to check for potential improvements.

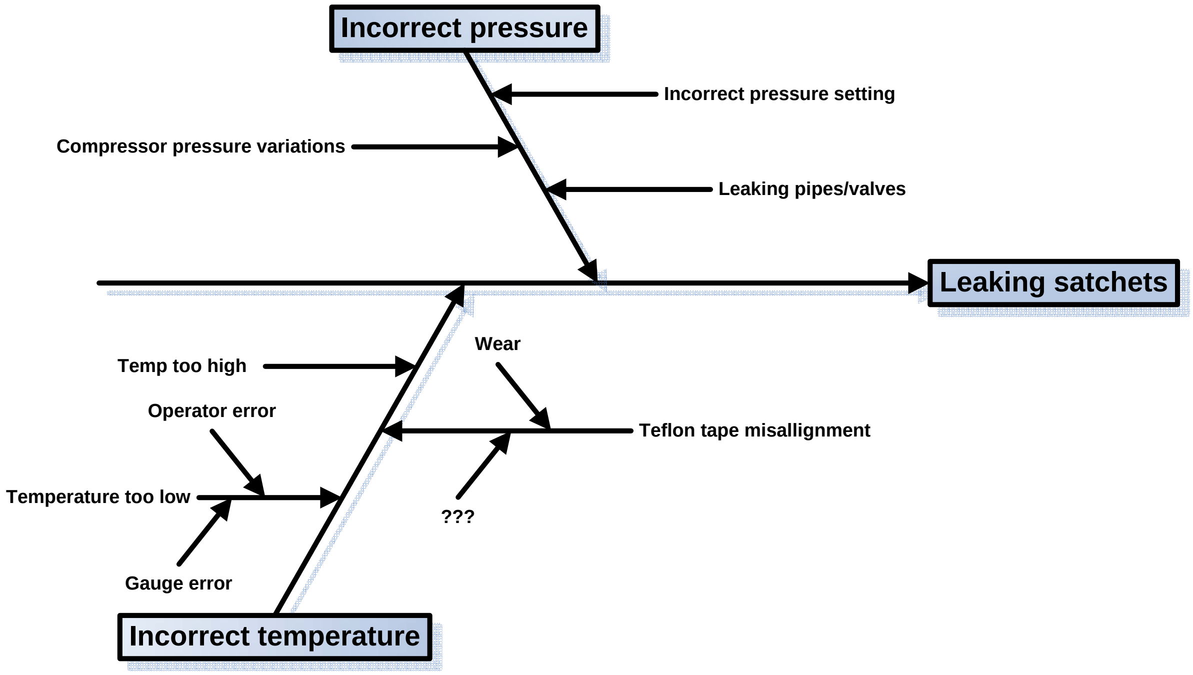

Figure 5.29: A fish bone diagram showing the identified causes of leaks

5.2.5.5 Control

Maintenance of charts especially in the lab would assist in predicting the failure of the packing machine. Evaluation of the causes of failure would assist in minimizing the failures.

5.2.5.6 Tools effectiveness rating

The tools used were then rated for effectiveness (High, Medium, or Low) by the researcher after the completion of the project. The reasons for the rating were given and were recorded in the last column of the Table 5.4.

Tool	Phase used	Effectiveness	Explanation
Flowchart	Define	High	Assisted in understanding the entire process and the sub-processes of interest. The key aspects were easily identifiable
Control chart	Measure/Improve	High	Indicated process performance accurately. It was also able to predict failure of the system and thus could be used as an indicator.
Cause and Effect Diagram	Analyze	Medium	Assisted in classifying the root cause of the program. Absence of a team hindered the effectiveness of this tool.
Design of Experiments	Improve	Low	Lack of management commitment to process improvement prevented the use of this tool. It would have been effective in identifying the critical process parameters for improvement

Table 5.4: A Table of the effectiveness rating of the used tools

CHAPTER SIX

6.0 CONCLUSION

Quality Management cannot be ensured without the application of the appropriate tools. Firms with greater implementation of QM tools can secure better performance than those with less implementation.

All the hypothesis were tested with various conclusions. General Hypothesis 1, that that kenyan manufacturing organizations in Kenya practice Quality Management Philosophies was found to be valid. General Hypothesis 2, that manufacturers in Kenya pursue Quality Management best practices was found to be valid. Of note however, was that human qualities associated with quality management scored least. Workforce flexibility, and shop floor idea generation are key requirements for quality management. The organizations are required to be stronger in improving human qualities and ensure their participation, in order to create a conducive work culture for quality.

General Hypothesis 3, that manufacturing firms in Kenya use traditional quality management tools was also found to be valid. The most commonly used tools are brainstorming, followed by check sheets and flow charts. These alone are not adequate to ensure quality. There is need for adoption of more quality tools to improve the levels of quality as different tools play different roles in the quality cycle. General Hypothesis 4, that manufacturing organizations use newer quality management tools was found to be false. These tools appear not to be used in any manufacturing organization in Kenya. This might be attributed to a general lack of awareness. In addition, these tools are more of management tools, rather than shop floor tools. This might indicate that the level of quality management to be at the shop floor level, with the management providing the requisite support but not using any tools themselves. Quality, however, begins at the top and the fact that management does not use these tools might indicate a Quality

Management gap at the top management.

General Hypothesis 5, that manufacturing firms in Kenya can identify the main areas of quality improvement that would be beneficial to the organization was found to be valid. This is important as quality management requires an understanding, or an appreciation of the existing problems. The two areas ranking highest, machinery and Process improvement, are the two areas that can be improved by the application of quality tools. This indicates that the organizations are generally aware of the problem, but lack the knowledge to solve the problem.

The comparative hypotheses were evaluated against four criteria: Adoption of Quality Management Principles; Understanding of the basic quality management principles; and Application of quality management tools. These were compared for large scale, medium scale, and Small scale organizations; Technology intensive and labor intensive organizations; Organizations targeting international market versus organizations targeting local markets; and older manufacturing organizations versus newer manufacturing organizations. Overall, it was found that large scale organizations practiced Continuous Improvement more than the small scale manufacturers. The small scale manufacturers were the practiced CI the least. Thus the model, developed in the research, targeting the small scale manufacturers, if used correctly could bridge the gap between levels of adoption between the large scale manufactures and the small scale manufacturers.

Technology intensive organizations were found to practice CI more than the labour intensive counterparts. However, labour intensive manufacturers applied the tools more than the technology intensive manufacturers. This can be explained by the fact that labor intensive manufacturers have more opportunities to use the quality tools by the very nature of their operations. The hypothesis was found to be true.

Manufacturers targeting international markets practice CI in their operations more than those targeting local markets. However the manufacturers targeting local markets are apply quality tools more than manufacturers targeting international markets. This can be attributed to the fact that even though the manufacturers for the international markets have more quality awareness, their manufacturing processes are also more technology intensive, requiring minimal use of traditional tools.

Comparative Hypothesis that older manufacturing organization practice CI in their operations, was found to be true. Younger organizations started between 1991 and 2008, showed greater levels of adoption of Quality Management Philosophies. However, older organizations showed better understanding of the basic quality management principles and greater application of quality management tools. Of note is that the uptake of the quality management tools in the shop floor is however below average for the three categories.

In general, both survey and case studies reveal that Small and Medium Scale manufacturers are still far behind in applications of various statistical and managerial methods or tools. They do not make full and efficient use of the tools and techniques available to them, and though they are generally aware of Quality Management and Continuous Improvement principles, there is an implementation gap. The attitudinal problem is the main hindrance for this status. The lack of the right kind of manpower coupled with lack of modern measuring methods and equipment and data processing devices are the other main reasons responsible for this. This problem is addressed in this research by the developed computer code.

Quality practices should be accepted as part of life in SMIs for self benefit. Advantages of application of the basic tools should be realized. Starting from personnel in design to implementation and evaluation, well-drawn training and development should be provided for them to understand the importance of the application of basic and advanced tools, and be able to apply them.

The overall results of the case study have appeared rewarding. The computer code was validated as a tool that can promote the use of quality tools to improve the quality of the firm's products. In the Company A, a 3% reduction in defects was recorded in the filter-making process. In company B, tools were used to predict failure from seemingly normal products as discussed. This provided a great opportunity for failure prediction, which improve the quality of the products.

The computer code, by its basic construction, provides the user with an initial quality tools from which to select. The research verified that the code provides the user with the information needed to select the correct quality tool at the correct phase. The computer program also assists the user in obtaining a basic understanding of a quality tool to determine if that is the correct tool to be used and if any other quality tools must precede its use. As also shown in the tools selection summaries and effectiveness rating tables, a tool may be used in more than one step in the process. The code presents clear instructions for the problem solver, especially if the problem solver is inexperienced. The code offers a limited number, but most often used, set of quality tools. It could easily be expanded to a wider set of tools.

CHAPTER SEVEN

7.0RECOMMENDATIONS

These valuable case studies provide the foundation for the application of quality tools. The computer code has proven to be a useful aid. The inexperienced quality management personnel have expressed an interest in an aid such as this. As a part of further development, a case by case database is proposed. The expanded database will keep track of tools used by problem type and serve as a "lessons learned" archive for future use in similar or related problems. This can be achieved by use of Neural Networks. The "lessons learned" archive can serve as a basis to help modify the code, by either expanding or reducing the tools included.

Since this application was limited to manufacturing firms, further study of how the code can be applied in the service industry could prove beneficial. Many of the techniques employed in manufacturing are now being applied to the ever-growing service sector. "Lessons learned" in service application, where there is heavy utilization of human capital versus physical capital, would provide an interesting case study and analysis.

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APPENDIX A

QUESTIONNAIRE

Survey of the Status of Continuous Improvement in the Kenya: A case study of Small and Medium scale manufacturers in Kenya

Department of Mechanical Engineering,
JKUAT

Introduction

This survey is a part of MSc study in Industrial Engineering by Mr. Zachary Kithinji, under the supervision of Professor S. M. Maranga, Department of Mechanical Engineering, JKUAT, and Mr. S. O. Nyamwange, Department of Management Science, University of Nairobi. The goal of this study is to investigate the status and the level of usage of Continuous Improvement (CI), with reference to the principle of Total Quality Management (TQM), in Small, Medium and Large Scale manufacturers in Kenya. This questionnaire is composed of five parts as follows;

Part I: General company information

Part II: Current implementation of Quality Management programs

Part III: Current usage of traditional and advanced Quality tools

Part IV: Areas of improvement that would be most beneficial to your company

Part V: Research interest

Benefits of the study to your company

This study aims to determine the needs of small and medium scale manufacturers for upgrading business performance through competitiveness with regard to Continuous Improvement aspect. The results obtained will be applicable to all the manufacturers under investigation, and hence, will be helpful to review your Quality Management strategy. If you are interested in obtaining this research results, please indicate your intention in the last part of the questionnaire, titled Research Interest.

Confidentiality

Your reply will be kept completely confidential and anonymous.

Filling in the questionnaire

This questionnaire seeks information from the manufacturing section, not the whole company. It is expected that the production manager, production engineer or quality assurance manager will respond to the questionnaire. Recognizing the respondent's valuable time, this questionnaire should require not more than 20 minutes to complete.

Follow-up interviews

This research study also planned to conduct some in-depth case studies by visiting plants and interviewing appropriate persons. Your willingness to be included in the case study will be very much appreciated. For this purpose, please indicate your intention in question B in the research interest section at the end of the questionnaire.

Contact person

Please return the completed questionnaire to:

Zachary Mwithiga Kithinji,
Department of Mechanical Engineering, JKUAT,
P.O. Box 62000 – 00200,
Nairobi.

Should you have any queries, please do not hesitate to contact me at:

E-mail: kithinjiz@eng.jkuat.ac.ke or Kithinjiz@yahoo.com
Telephone: 067 – 52711 ext 2330
Mobile: 0721 – 55 70 80

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1. **<u>General Company Information</u>**

1.1. How many employees does your company employ? (Please tick one)

( ) Less than 50 ( ) Between 50 – 100

( ) More than 100

1.2. When was your company established? Year………………

1.3. Which manufacturing sector does your organization belong to? (Please write down one sector. If not sure select the most appropriate one from the list attached as Appendix 1)

…………………………………………………………………..

1.4. Manufacturing is classified as labour-intensive or technology-intensive. What is the main mode of manufacture by which your products are made? (Please tick one)

( ) Labour-intensive products ( ) Technology-intensive products

1.5. What is the target market for your products? Supply to: (Please tick one)

( ) Only domestic market ( ) Only international market

( ) Domestic market more than International market

( ) Domestic market equal to International market

( ) Domestic market less than International market

2. **The Current Implementation of Quality Management**

<u>Definition:</u> Quality Management means an approach to achieve customer satisfaction by manufacturing quality products through continuous improvements in manufacturing process by seeking continual improvement of machinery, materials, labour utilization, product design and production methods.

2.1. Please circle the figure showing whether your plant adopts the following Quality Management programs.

Key to the figures

1 = No. There is no plan for implementation

2 = No. But there is a plan to implement

3 = Yes. It is partially implemented

4 =Yes. It is fully implemented.

Adoption of Quality Management Philosophies	**Implementation**			
a) TQM Program	1	2	3	4
b) Achieving quality certification (e.g. ISO 9000, ISO 14000 etc) Please specify…………………….	1	2	3	4
c) Quality Improvement activities through Kaizen (e.g. 5S activities, Quality Councils etc)	1	2	3	4
d) Statistical Quality Control (SQC)	1	2	3	4
e) Six Sigma	1	2	3	4
f) Any best practices (e.g. Lean manufacturing, JIT, TPM) Please specify…………….	1	2	3	4

2.2. Please circle the figure indicating the status of your organization with regard to the following practices that pertain to quality management.

	Strongly disagree	Disagree	Agree	Strongly agree
a) Documentation is clear and up-to-date	1	2	3	4
b) There is need for continual change	1	2	3	4
c) The facility is (completely) reliable	1	2	3	4
d) Organization is committed to total quality and CI	1	2	3	4
e) The workforce is flexible	1	2	3	4
f) Organization is committed to training	1	2	3	4
g) We always achieve the shortest possible throughput time	1	2	3	4
h) The reduction of manufacturing costs is appreciable	1	2	3	4
i) The manufacturing lead times are measurable in terms of days/hours	1	2	3	4
j) All sorts of waste/misuse are removed	1	2	3	4
k) The shop floor is a source of ideas	1	2	3	4
l) The inventory turnover is satisfactory	1	2	3	4

2.3. Has your plant ever participated in a Quality Management award? (Please tick one or more)

( ) Never

( ) Yes. Local award. Please specify……………………………………

( ) Yes. International award. Please specify…………………………….

3. **Current usage of traditional and advanced quality tools**

3.1. Which of tools and techniques below has your company applied, and how applicable and effective are they? (Please circle a number for applicability and a number for effectiveness)

Tools and Techniques **Traditional Quality Tools**	***Applicability*** ***Never…………Always***					***Effectiveness*** ***Nil……….Very high***				
a) Pareto diagram	0	1	2	3	4	0	1	2	3	4
b) Cause and effect diagram	0	1	2	3	4	0	1	2	3	4
c) Brainstorming	0	1	2	3	4	0	1	2	3	4
d) Flow charts	0	1	2	3	4	0	1	2	3	4
e) Check sheets	0	1	2	3	4	0	1	2	3	4
f) Histogram	0	1	2	3	4	0	1	2	3	4
g) SPC control charts	0	1	2	3	4	0	1	2	3	4
h) Scatter diagram	0	1	2	3	4	0	1	2	3	4
i) Design of Experiments	0	1	2	3	4	0	1	2	3	4
j) Failure Mode and Effect Analysis (FMEA)	0	1	2	3	4	0	1	2	3	4
k) Capability Analysis	0	1	2	3	4	0	1	2	3	4
l) Mistake proofing	0	1	2	3	4	0	1	2	3	4
m) Box plot	0	1	2	3	4	0	1	2	3	4
n) New Quality Management tools(Affinity, Tree, Matrix, Activity network diagrams; Interrelationship diagraph, Process Decision Program Chart) Please Specify………....... …………………………..	0	1	2	3	4	0	1	2	3	4

4. **Areas of Improvement that would be beneficial to your company**

4.1. Please circle one number indicating how often the following plant resources and operational tasks listed below contribute to presence of defects in the final products

Plant resources and operational tasks	**Frequency of defects**			
	Nil	**Few**	**Some**	**Often**
a) Raw material	0	1	2	3
b) Operators	0	1	2	3
c) Processes	0	1	2	3
d) Machinery	0	1	2	3
e) Others. Please specify ……………………………………….	0	1	2	3

4.2. Which of the following manufacturing ‘best practices’ does your plant strive to achieve? (Please tick one or more)

( ) Improved quality

( ) Up-to-date Process documentation

( ) Increased Productivity

( ) Cycle time reduction

( ) Inventory reduction

( ) Waste reduction

( ) Other, Please specify……………………………………………………

5. **Research Interest**

A. Are you interested in obtaining the results of this study

( ) Yes ( ) No

If yes please indicate the name of your organization

…………………………………………………………………………………..

B. Would your plant be prepared to be included in the case study?

( ) Yes ( ) No

C. Would you have any other relevant comments to make relevant in relation to this study?

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Thank you for your cooperation

APPENDIX B

TOOLS CLASSIFICATION

Table B.1: Tools Attributes Classification

	Attributes											
	Categorizations				Inputs to tool			Outputs of tool				
Quality Tool	Six Sigma phase	Demming wheel phase	Type of tool	Skill of user	What is needed for tool use	Quality tools needed prior to using this tool	What the tool works with	Tool function	Tool classification	Physical outcome	What the tool does with information
Thought Process map	Define	Plan	Clerical	Novice	Process knowledge	None	Ideas	Generates /groups /decides /implements	Document	Matrix	Organizes
Check sheet	Define/ Measure	Plan	Analytical	Novice	Data collection	None	Numbers	Counts	Tool	Matrix	Organizes / classifies /prioritizes
Cause and effect matrix	Define /Measure /Improve	Plan /Do	Analytical	Novice	Process knowledge	Process map	Ideas	Generates /groups /implements	Document	Matrix	Organizes / classifies /prioritizes
Cause and effect diagram	Define /Measure /Analyze	Plan /Do	Analytical	Novice	Process knowledge	None	Ideas	Generates /groups /implements	Tool	Diagram	Organizes / classifies /prioritizes
Flow chart	Define /Measure /Analyze /Improve /Control	Plan /Do /Check /Act	Analytical	Novice	Process knowledge	None	Ideas	Generates /groups /decides /implements	Tool	Diagram	Organizes /prioritizes
FMEA	Define /Measure /Improve	Plan /Do	Analytical	Advanced	Process knowledge	Control plan/ C&E matrix/ process map	Ideas	Generates /groups /decides	Technique	Matrix	Organizes / classifies /prioritizes
Capability Analysis	Measure /Analyze /Improve	Do /Check	Statistical	Intermediate	Data collection	Control charts	Numbers	Measures /counts	Tool	Numerical analysis	Analyzes /compares
Pareto Diagram	Measure /Analyze /Improve /Control	Plan /Do /Check /Act	Analytical	Novice	Data collection	Check sheets	Numbers	Counts	Tool	Diagram	Organizes / classifies /prioritizes
Design of Experiments	Analyze /Improve	Do /Check	Statistical	Advanced	Data collection /numerical analysis	Multivariate analysis/ cause and effect diagram/matrix	Numbers	Measures	Technique	Matrix	Organizes / classifies /prioritizes / compares
Cost Benefit Analysis	Improve	Check /Act	Clerical	Novice	Process knowledge /numerical analysis	None	Ideas	Implements	Document	Numerical analysis	Compares /prioritizes
Control plan	Improve /Control	Check /Act	Clerical	Intermediate	Process knowledge	Cause and effect matrix /flow chart	Ideas	Generates /groups /implements	Document	Matrix	Organizes /prioritizes /implements
Mistake proofing	Control	Act	Analytical	Advanced	Process knowledge	None	Ideas	Implements	Technique	Change in process	Implements
Gauge repeatability	Measure /Analyze	Do / check	Statistical	Intermediate	Data collection /numerical analysis	None	Numbers	Measures	Technique	Numerical analysis /charts	Compares /proves

Table B.2: Tools Attributes Classification cont'd

Trend run	Measure/ Analyze /Improve /Control	Do /check /Act	Analytical	Novice	Data collection	None	Numbers	Counts /measures	Tool	charts	Provides status /predicts
Control charts	Measure/ Analyze /Improve /Control	Do /check /Act	Statistical	Intermediate	Data collection /numerical analysis	None	Numbers	Counts /measures	Tool	charts	Provides status /predicts /compares
Histogram	Measure/ Analyze	Do / Check	Statistical	Novice	Data collection	Control charts	Numbers	Counts /measures	Tool	Diagram	Organizes/ provides status /
Scatter diagram	Measure/ Analyze	Do /Check	Statistical	Intermediate	Data collection	None	Numbers	Counts /measures	Tool	Diagram	Organizes/ provides status /
Box plot	Measure/ Analyze	Do /Check	Statistical	Intermediate	Data collection	Control charts	Numbers	Counts /measures	Tool	Diagram	Organizes/ provides status /
Multivariate charts	Analyze /Control	Check /Act	Statistical	Intermediate	Data collection	Control charts	Numbers	Counts /measures	Tool	Diagram	Organizes / Compares
Hypothesis testing	Measure/ Analyze /Improve	/Do /Check /Act	Statistical	Advanced	Data collection /numerical analysis	Control charts	Numbers	Measures	Tool	Numerical analysis	Organizes / Compares

APPENDIX C

FLOWCHART OF THE PROGRAM

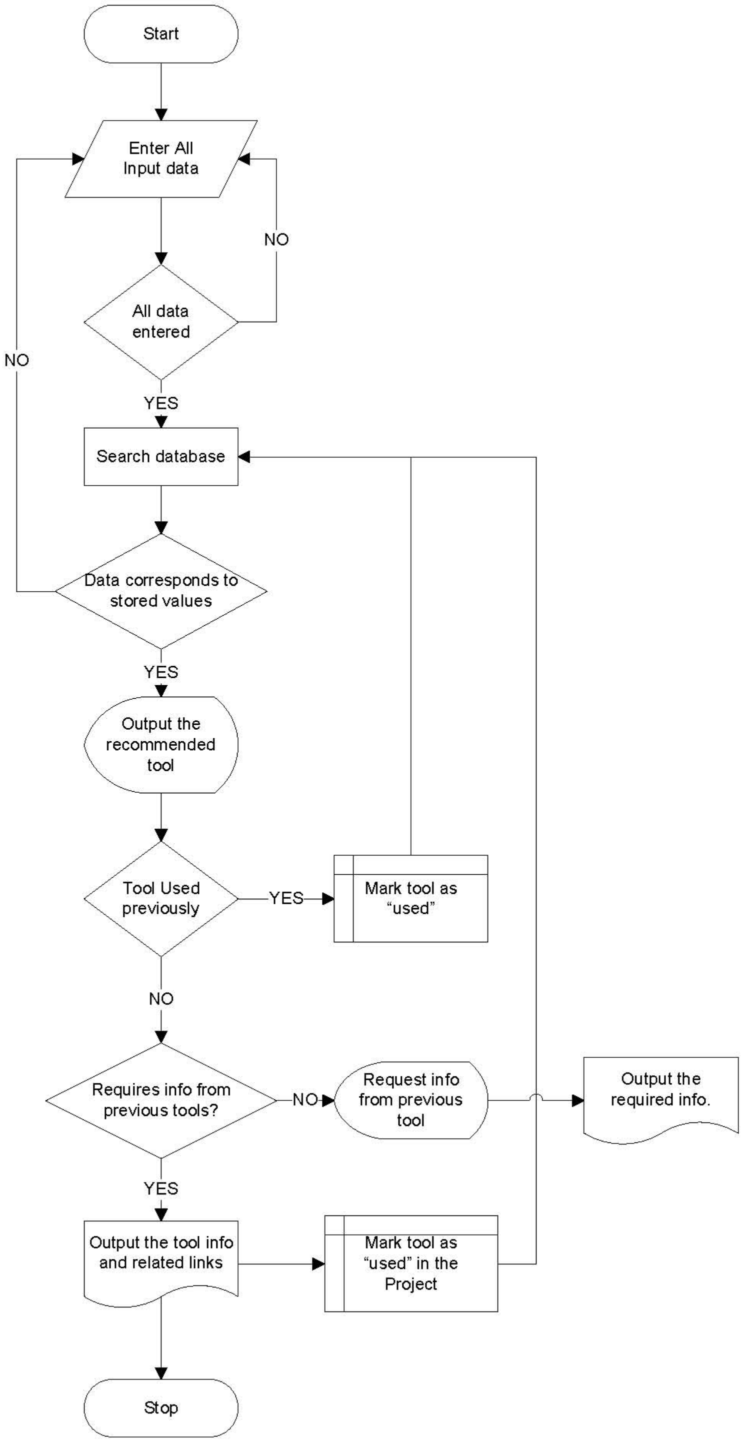


Figure C.1: Flowchart of the Model

APPENDIX D

QUALITY TOOLS

Checksheet

A check sheet is a structured, prepared form for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes. The FigureD.1 below shows an example of a check sheet used to collect data on telephone interruptions. The tick marks were added as data was collected over several weeks.

Telephone Interruptions

Reason	Day					
	Mon	Tues	Wed	Thurs	Fri	Total
Wrong number	𝍸	II	I	𝍸	𝍸 II	20
Info request	II	II	II	II	II	10
Boss	𝍸	II	𝍸 II	I	IIII	19
Total	12	6	10	8	13	49

Figure D.1: An example of a check sheet (Source: Nancy R. Tague's, The Quality Toolbox)

Pareto Chart

It is a graph of bar chart that rank causes of a problem in descending order of significant that reflects impact, frequency or importance. The Pareto rule states that 80 percent of the problems comes from 20 percent of the causes. The Pareto principle enables effort to be designated to the vital 20 percent of the causes of the problems. The FigureD.2 below shows an example of a Pareto Chart used to rank the categories of document-related complaints in an organization.

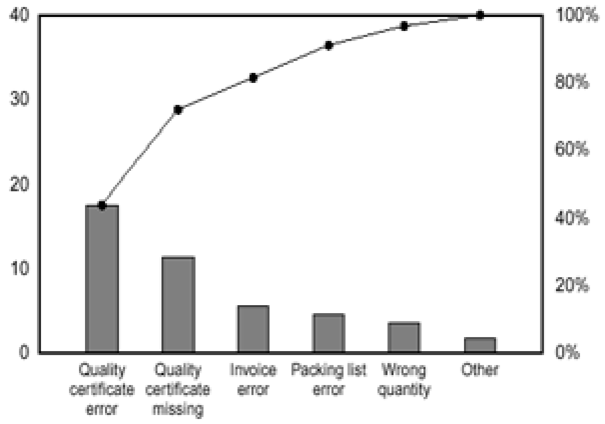


Figure D.2: An example of a Pareto Chart (Source: Nancy R. Tague's, The Quality Toolbox)

Scatter Diagram

The scatter diagram graphs pairs of numerical data, with one variable on each axis, to look for a relationship between them. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line. Below is an example of a scatter diagram to determine whether there is a correlation between product purity (percent purity) and the amount of iron (measured in parts per million or ppm). Purity and iron are plotted against each other as a scatter diagram, as shown in the FigureD.3 below. There is no correlation.

Control Charts

Control charts are used to identify and differentiate between common and special causes of variation. When a process no longer exhibits special variation, but only common variation, it is said to be stable. When only common causes of variation are present in a process, management must take action to reduce the difference between customer needs and process performance by endeavoring to move the centerline of the process closer to a desired level (nominal) and/or by reducing the magnitude of common variation. Deming

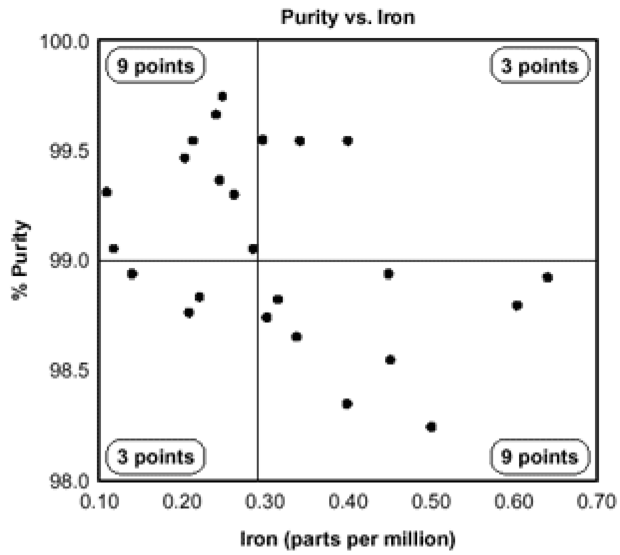


Figure D.3: An example of a Scatter Diagram (Source: Nancy R. Tague's, The Quality Toolbox)

wrote, "It is good management to reduce the variation in any quality characteristic, whether this characteristic be in a state of control or not, and even when few or no defectives are being produced."

Structure and Construction of Control Charts

All control charts have a common structure. They have a centerline (representing the process average) and upper and lower control limits (called 3-sigma limits) that provide information on the process variation. The area between the control limits is divided into six bands, each band one standard error wide. The bands within one standard error of the centerline are called the C zones; bands between one and two standard errors from the centerline are called B zones; and the outermost bands, which lie between two and three standard errors from the mean, are A zones as shown in Figure D.4 below. Seven simple rules based on these bands are commonly applied to determine if a process is exhibiting a lack of statistical control.

Rule 1. A process exhibits a lack of control if any subgroup statistic falls outside of the

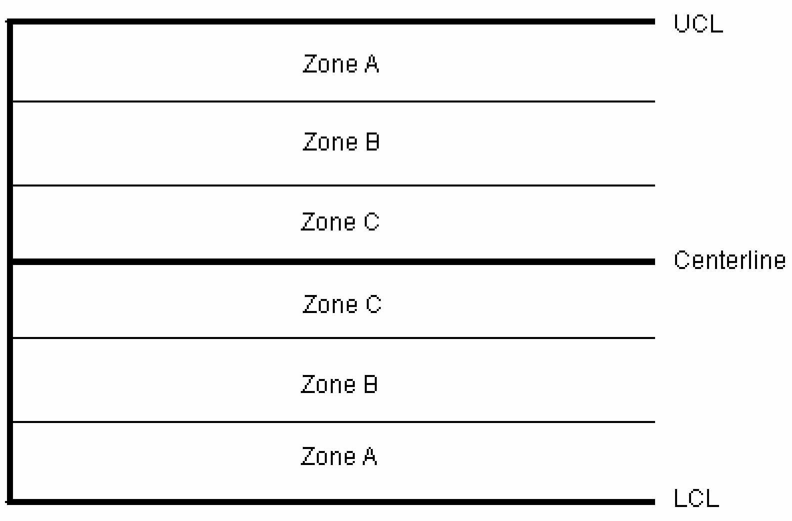


Figure D.4: Structure of a control chart

control limits.

Rule 2. A process exhibits a lack of control if any two out of three consecutive subgroup statistics fall in one of the A zones or beyond on the same side of the centerline as shown in Figure D.5 below. The points marked X indicate the out-of-control points.

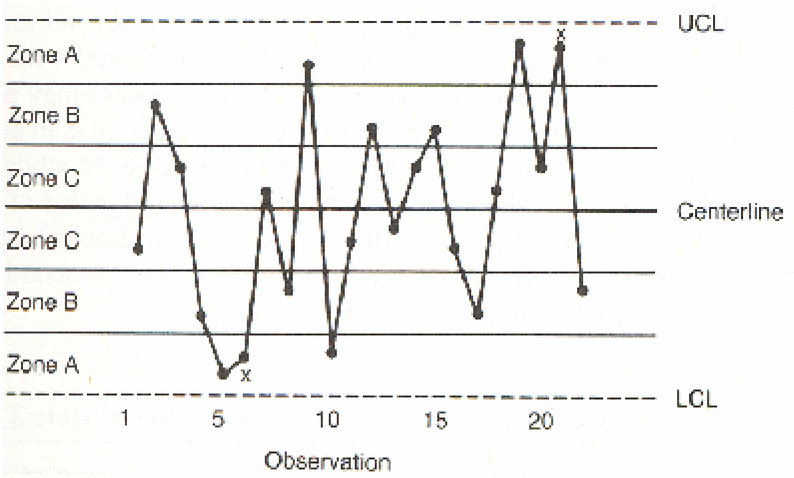


Figure D.5: Rule 2

Rule 3. A process exhibits a lack of control if four out of five consecutive subgroup statistics fall in one of the B zones or beyond on the same side of the centerline as shown in Figure D.6 below.

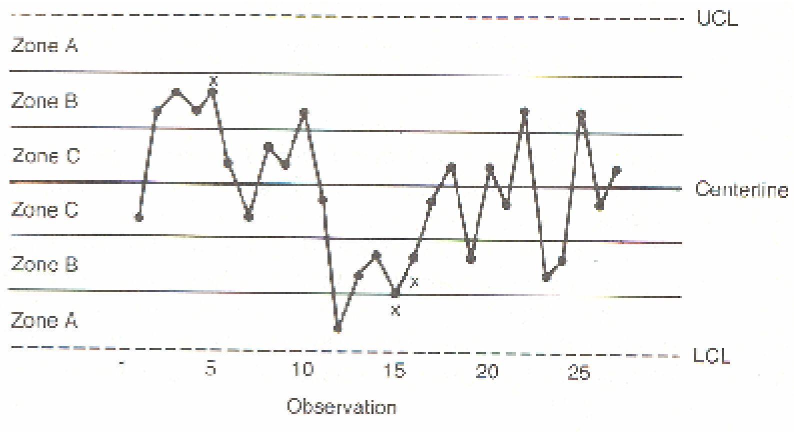


Figure D.6: Rule 3

Rule 4. A process exhibits a lack of control if eight or more consecutive subgroup statistics lie on the same side of the centerline as shown in Figure D.7 below.

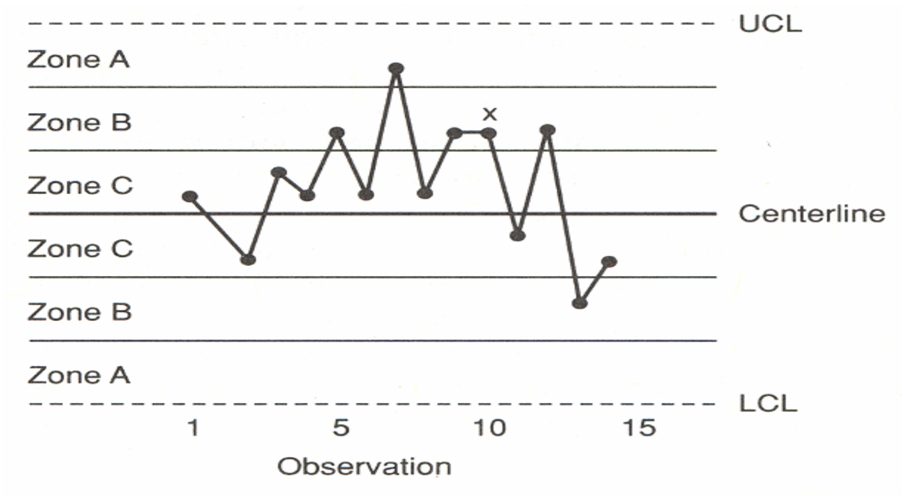


Figure D.7: Rule 4

Rule 5. A process exhibits a lack of control if eight or more consecutive subgroup statistics move upward in value or if eight or more consecutive subgroup statistics move downward in value as shown in Figure D.8 below.

Rule 6. A process exhibits a lack of control if an unusually small number of runs above and below the centerline are present (a saw-tooth pattern) as shown in Figure D.9 below.

Rule 7. A process exhibits a lack of control if 13 consecutive points fall within zone C

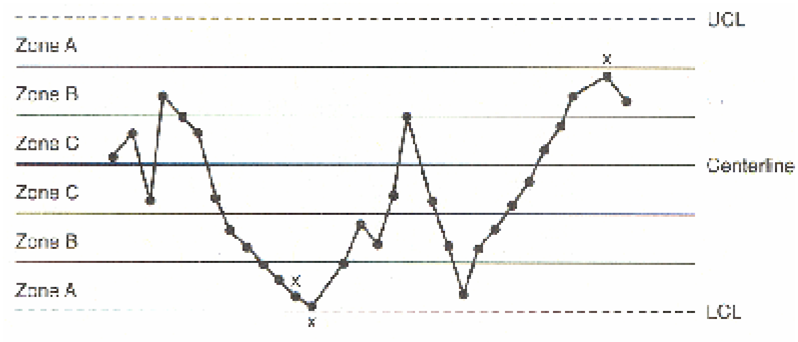


Figure D.8: Rule 5

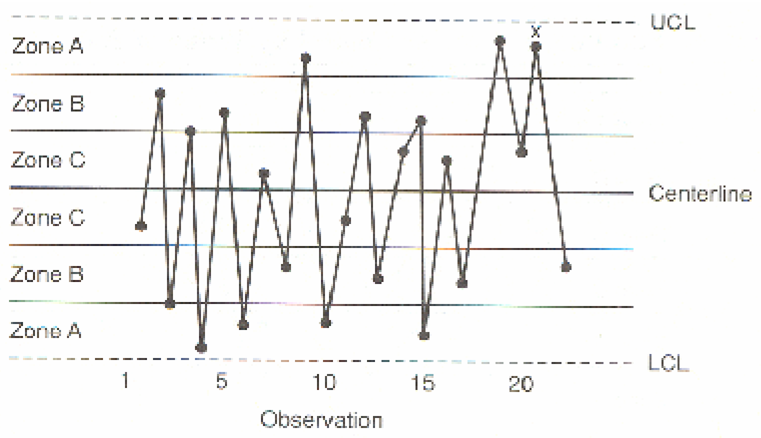


Figure D.9: Rule 6

on either side of the centerline as shown in Figure D.10 below.

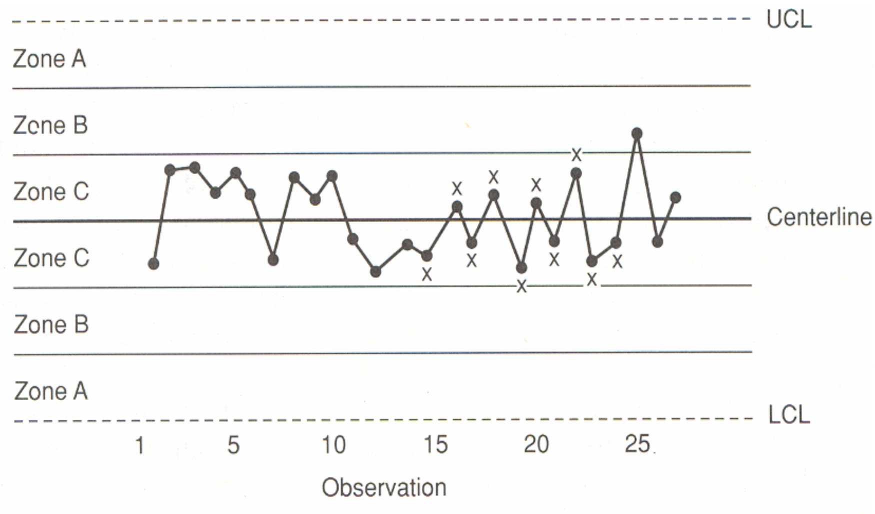
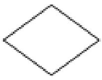
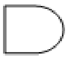
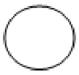
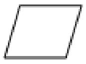
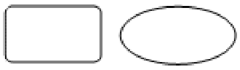


Figure D.10: Rule 7

Table D.1: Commonly Used Symbols in Detailed Flowcharts

Symbol	Meaning
	One step in the process; the step is written inside the box. Usually, only one arrow goes out of the box.
	Direction of flow from one step or decision to another.
	Decision based on a question. The question is written in the diamond. More than one arrow goes out of the diamond, each one showing the direction the process takes for a given answer to the question. (Often the answers are "yes" and "no")
	Delay or wait
	Link to another page or another flowchart. The same symbol on the other page indicates that the flow continues there.
	Input or output
	Document
	Alternate symbols for start and end points

Flow Chart or Process Mapping

A flowchart is a picture of the separate steps of a process in sequential order. Elements that may be included are: sequence of actions, materials or services entering or leaving the process (inputs and outputs), decisions that must be made, people who become involved, time involved at each step and/or process measurements. The process described can be anything: a manufacturing process, an administrative or service process, a project plan. This is a generic tool that can be adapted for a wide variety of purposes. The commonly used figures are shown in the TableD.1.

Cause and Effect or Fish Bone Diagram

It was developed by Kauro Ishikawa [20] and is method for analyzing a process showing the main and sub causes of a problem and their effects. It can be used to structure a brainstorming session. It immediately sorts ideas into useful categories. FigureD.11 shows an example of a fishbone diagram created by a manufacturing team to try to understand the source of periodic iron contamination. The team used the six generic headings to prompt ideas.

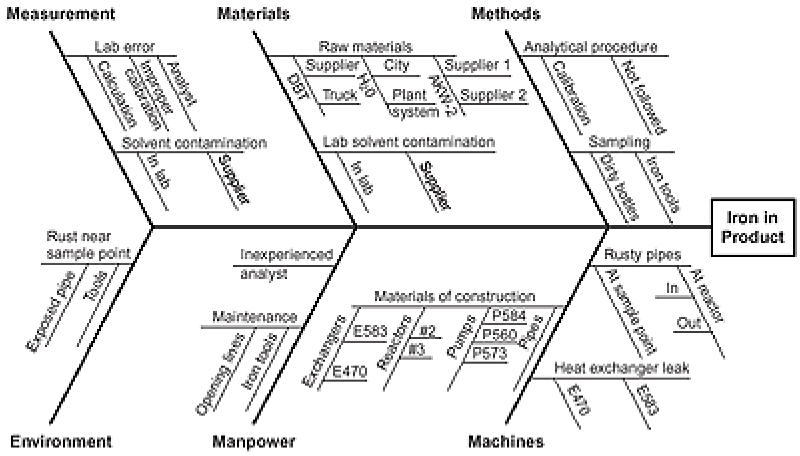


Figure D.11: An example of a fish bone diagram

Histogram

It is a graphical summary of a set of data that reveals the amount variation that a process has. The peaks allow individual to see the patterns that are difficult to identify from a table. There are several types of distributions as shown in the FigureD.12 In a normal distribution, points are as likely to occur on one side of the average as on the other. The skewed distribution is asymmetrical because a natural limit prevents outcomes on one side. The distribution's peak is off center toward the limit and a tail stretches away from it. These distributions are called right- or left-skewed according to the direction of the tail.

In the bimodal distribution, the outcomes of two processes with different distributions are combined in one set of data. The plateau distribution might be called a "multimodal

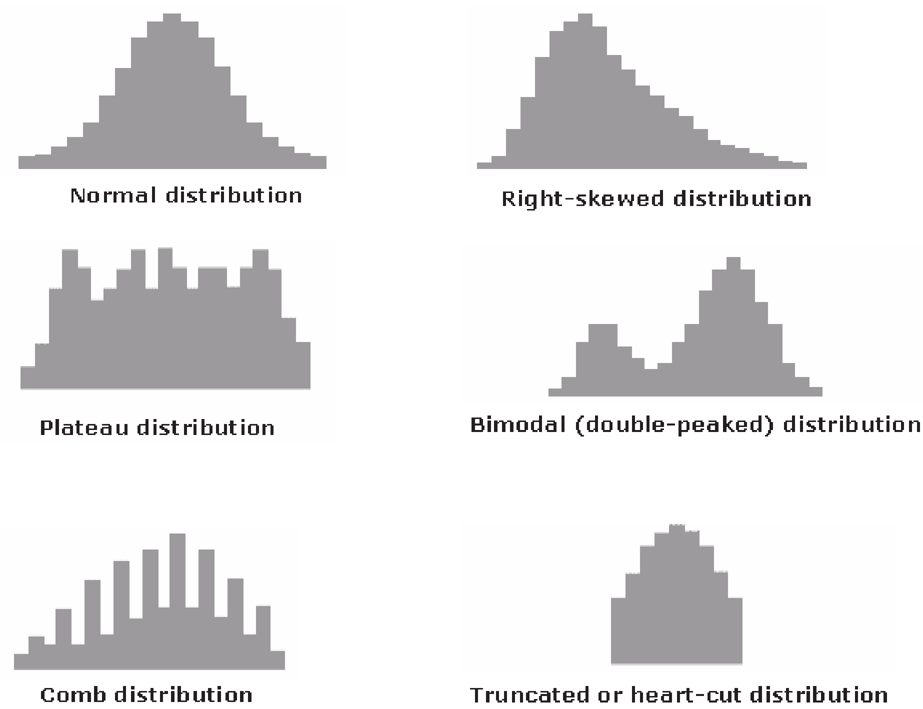


Figure D.12: Some common shapes of histograms distributions

distribution." Several processes with normal distributions are combined. Because there are many peaks close together, the top of the distribution resembles a plateau.

The edge peak distribution looks like the normal distribution except that it has a large peak at one tail. This is usually caused by faulty construction of the histogram, with data lumped together into a group labeled "greater than" The truncated distribution looks like a normal distribution with the tails cut off. The supplier might be producing a normal distribution of material and then relying on inspection to separate what is within specification limits from what is out of specifications.

Design of Experiments

Design of experiments (DoE) is a collection of statistical methods for studying the relationships between independent variables, the Xs (also called factors, input variables, or process variables), and their interactions on a dependent variable, Y (also called the outcome or response variable) [25]. It is a technique that can be used to minimize the effects of background variables on understanding the relationship between the X(s) and Y. A background variable (also called noise variable or lurking variable) is a variable that can potentially affect the dependent variable (Y) in an experiment, but is not of interest as an independent variable (X). The concepts of experimental design discussed here represent an active intervention into a process by employees, that is, process changes are planned and tested by employees, and the data caused by those changes are studied to determine the effect of the process change.

Types of Designs

1. Screening designs

   These are used when there is a low level of knowledge about the Xs that are critical to optimizing Y. Researchers use these experiments to identify the key Xs to optimizing Y, using very few trials.

2. Full factorial designs

   These are used when there is a low level of knowledge of the interactions between the key Xs necessary to optimizing Y.

3. Fractional factorial designs

   These are used when there is a moderate level of knowledge about the interactions between the key Xs needed to optimize Y, using an economical number of trials.

4. Response surface methodology trials

   These are used when there is a high level of knowledge about the key Xs, and their interactions, needed to optimize Y.

Affinity Diagram

The affinity diagram organizes a large number of ideas into their natural relationships. This method taps a team's creativity and intuition. It was created in the 1960s by Japanese anthropologist Jiro Kawakita. It involves grouping the ideas into clusters of related ideas. It can be viewed as the opposite of fish bone diagram.

Relations Diagram

The relations diagram shows cause-and-effect relationships. Just as importantly, the process of creating a relations diagram helps a group analyze the natural links between different aspects of a complex situation. FigureD.13 shows an example of a relations diagram for a team planning the replacement of a mainframe computer.

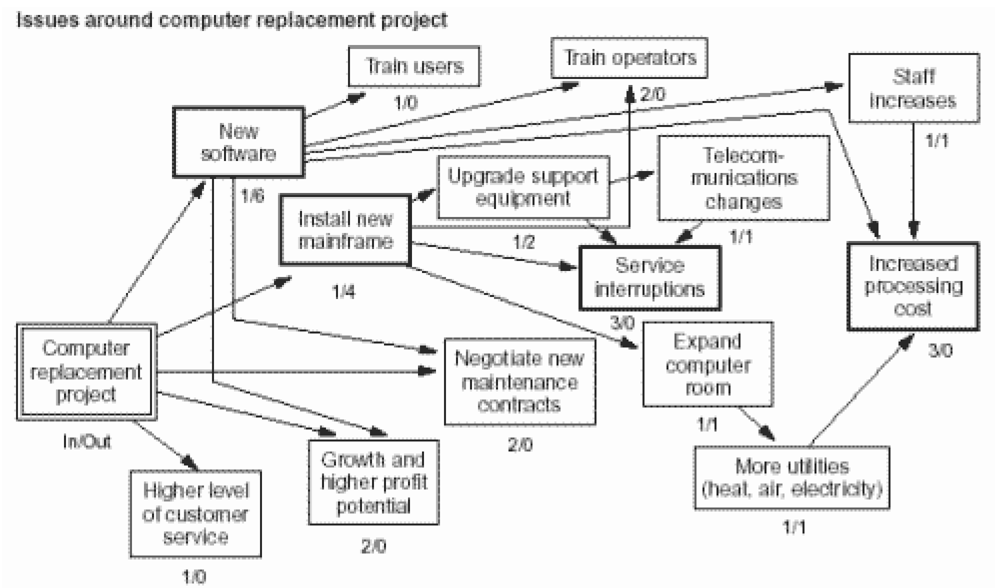


Figure D.13: An example of a relations diagram

Tree Diagram

The tree diagram starts with one item that branches into two or more, each of which branch into two or more, and so on. It looks like a tree, with trunk and multiple branches. It is used to break down broad categories into finer and finer levels of detail. Developing the tree diagram helps you move your thinking step by step from generalities to specifics as shown in FigureD.14.

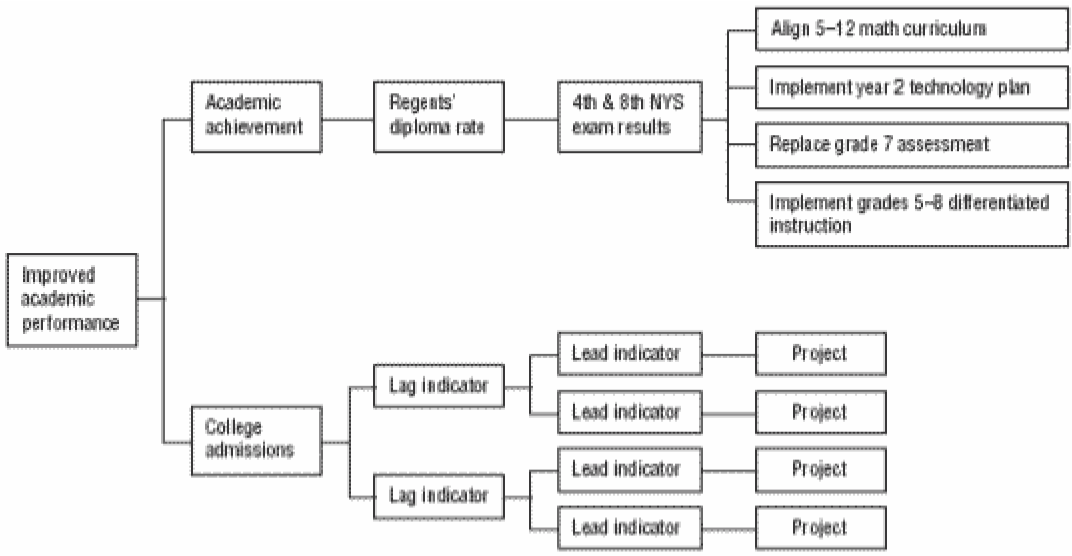


Figure D.14: An example of a tree diagram

Matrix diagram

The matrix diagram shows the relationship between two, three or four groups of information. It also can give information about the relationship, such as its strength, the roles played by various individuals or measurements. FigureD.15 shows an example of a 'responsibilities for performance to customer requirements' matrix diagram

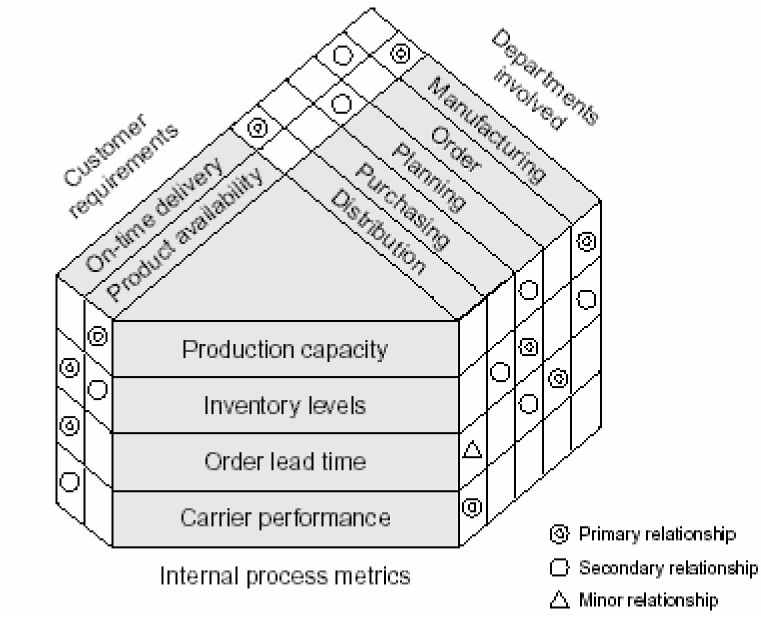


Figure D.15: An example of a matrix diagram

Matrix Data Analysis

This is a complex mathematical technique for analyzing matrices, often replaced in this list by the similar prioritization matrix. It is one of the most rigorous, careful and time-consuming of decision-making tools that uses pairwise comparisons of a list of options to a set of criteria, in order to choose the best option(s).

Arrow Diagram

The arrow diagram shows the required order of tasks in a project or process, the best schedule for the entire project, and potential scheduling and resource problems and their solutions. The arrow diagram lets you calculate the "critical path" of the project. This is the flow of critical steps where delays will affect the timing of the entire project and where addition of resources can speed up the project.

Process Decision Program Chart (PDPC)

The process decision program chart systematically identifies what might go wrong in a plan under development. Countermeasures are developed to prevent or offset those problems. By using PDPC, you can either revise the plan to avoid the problems or be ready with the best response when a problem occurs. An example is shown in FigureD.16

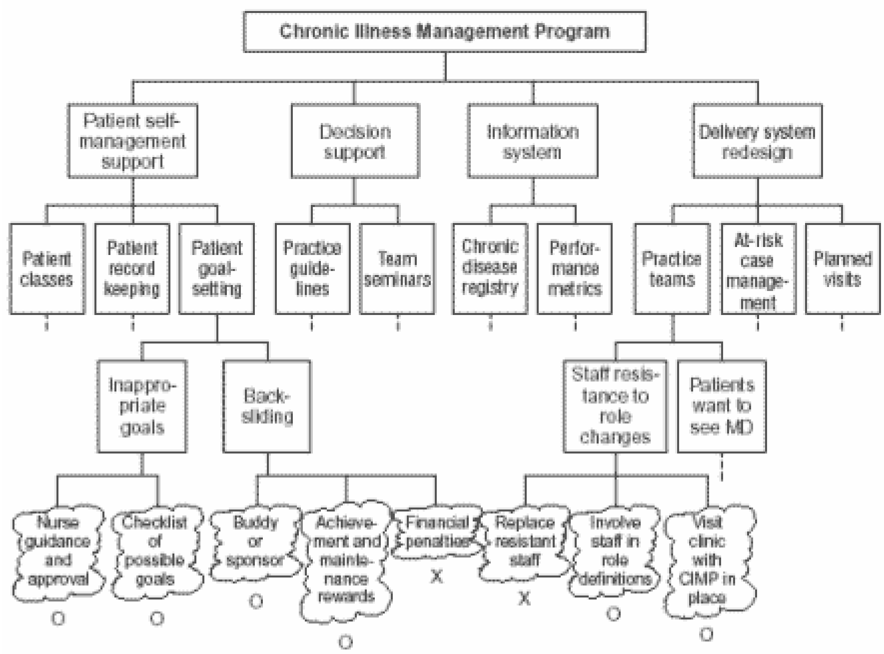


Figure D.16: An example of a Process decision program chart (PDPC)

Failure Mode and Effects Analysis (FMEA)

Failure modes and effects analysis (FMEA) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service. "Failure modes" means the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual. "Effects analysis" refers to studying the consequences of those failures. Failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones. Failure modes and effects analysis also documents current knowledge and actions about the risks of failures, for use in continuous improvement. FMEA is used during design to prevent failures. Later it's used for control, before and during ongoing operation of the process. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service. Begun in the 1940s by the U.S. military, FMEA was further developed by the aerospace and automotive industries. Several industries maintain formal FMEA standards. An example of an FMEA done for a bank's ATM machine is shown in FigureD.17

Function	Potential Failure Mode	Potential Effects(s) of Failure	S	Potential Cause(s) of Failure	O	Current Process Controls	D	RPN	CRIT	Recommended Action(s)	Responsibility and Target Completion Date	Action Results					
												Action Taken	S	O	D	RPN	CRIT
Dispense amount of cash requested by customer	Does not dispense cash	Customer very dissatisfied Incorrect entry to demand deposit system Discrepancy in cash balancing	8	Out of cash	5	Internal low-cash alert	5	200	40								
				Machine jams	3	Internal jam alert	10	240	24								
				Power failure during transaction	2	None	10	160	16								
	Dispenses too much cash	Bank loses money Discrepancy in cash balancing	6	Bills stuck together	2	Loading procedure (riffle ends of stack)	7	84	12								
				Denominations in wrong trays	3	Two-person visual verification	4	72	18								
	Takes too long to dispense cash	Customer somewhat annoyed	3	Heavy computer network traffic	7	None	10	210	21								
				Power interruption during transaction	2	None	10	60	6								

Figure D.17: An example of a FMEA sheet